HEALTH SYSTEMS PERFORMANCE AND NON-COMMUNICABLE DISEASES: MEASURING EFFECTIVE COVERAGE OF HYPERTENSION MANAGEMENT IN RURAL BIHAR, INDIA

by
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Abstract

In 2010, over one billion people in low- and middle-income countries (LMICs) were living with hypertension. With the steadily rising global burden of non-communicable diseases, a vital responsibility of local and national health systems within the universal health coverage agenda is to provide services that can effectively manage chronic diseases, such as hypertension. Cost-effective interventions at the primary health care level can avert over one million hypertension-related deaths per year in LMICs, however there is a paucity of evidence on how to assess a health system's ability to provide hypertension management services of sufficient quality to improve population health. This dissertation expands upon previous research and develops new methods to advance the measurement of effective coverage of hypertension management services in LMICs.

The thesis reviews published works that describe the effective coverage of hypertension management services or the quality of these services received at a population level (Chapter 2). Findings from this review inform the development of a measurement framework – the expanded hypertension cascade of care – which describes barriers to achieving effective hypertension management in LMICs. The expanded hypertension cascade of care is applied to rural Bihar (one of India's poorest states with a rural population of 92 million people) to assess these barriers in a real-world setting (Chapter 3). Barriers to hypertension management highlighted in the first two studies inform the development of a comprehensive index metric to describe the effective coverage of hypertension management services in rural Bihar (Chapter 4). Nested within a larger assessment of the primary health care system in rural Bihar, data collection includes a household survey on care-seeking behaviors with a sample of 39,486 individuals from 343 villages, as well

as a provider assessment comprising of a facility readiness survey, clinical vignettes (including one on hypertension diagnosis and management), and direct patient observations with a sample of 390 public and private primary care providers across 70 villages.

We found eight separate attempts to define effective coverage for hypertension management services, and 12 additional studies which reported population-level receipt of quality hypertension management services. From these articles, common barriers to hypertension management in LMICs were (i) screening populations for high blood pressure, (ii) linkage to hypertension care that adhered to clinical guidelines, and (iii) adhering to prescribed treatment. Measurement following the expanded hypertension cascade of care identified nearly 6.6 million undiagnosed hypertensive individuals over the age of 30 in rural Bihar, 2.1 million of which have never had their blood pressure measured before. Although nearly all diagnosed hypertensive individuals were able to seek care, as few as one-fifth sought care from providers who demonstrated sufficient knowledge on how to diagnose and appropriately treat hypertension. While the coverage of key hypertension management services was 70%, the quality-adjusted coverage of these services was 31% across the state.

Results from this dissertation reflect the urgent need to improve the quality of hypertension management services available in rural Bihar and other LMIC contexts. Expanding (and measuring) service coverage alone is not enough to reduce the burden of disease in LMICs. Tracking the effective coverage of hypertension management services is an important component of evaluating health systems performance, and highlights a different set of interventions that are needed to improve population health in the non-communicable disease era. This research can

help to bridge the gap between health systems metrics and improved lives for people living with hypertension around the world.

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Table of Contents

List of Tables:

List of Figures:

Abbreviations

AB	Ayushman Bharat
ACC	American College of Cardiology
AHA	American Heart Association;
AIDS	Acquired Immunodeficiency Syndrome
ANC	Antenatal Care
APHCB	Assessment of Primary Health Care in Bihar Study
AYUSH	Ayurveda, Yoga and Naturopathy, Unani, Siddha, and Homeopathy
BMGF	Bill and Melinda Gates Foundation
BP	Blood Pressure
BTSP	Bihar Technical Support Program
CAPI	Computer-Assisted Personal Interviewing
CDC	Centers for Disease Control and Prevention
CHC	Community Health Center
COVID-19	Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2)
DALY	Disability Adjusted Life Year
DHS	Demographic and Health Surveys
DTP	Diphtheria-Tetanus-Pertussis
ESC	European Society of Cardiology
ESH	European Society of Hypertension
GoB	Government of Bihar
HIV	Human Immunodeficiency Virus
HMSCI	Hypertension Management Service Coverage Index
HWC	Health and Wellness Centre
IGH	Indian Guidelines on Hypertension
IHME	Institute for Health Metrics and Evaluation
IP	Informal Provider
JNC 8	Eighth Joint National Committee
LMICs	Low- and Middle-Income Countries
mm Hg	Millimeters of Mercury
MBBS	Bachelor of Medicine and Bachelor of Surgery
NCD	Non-Communicable Disease
NFHS	National Family Health Survey
NGO	Non-Government Organization
NPCDCS	National Programme for Prevention & Control of Cancer, Diabetes, Cardiovascular Diseases & Stroke
NSS	National Sample Survey
OECD	Organisation for Economic Co-operation and Development
PHC	Primary Health Center
SDG	Sustainable Development Goal
UHC	Universal Health Coverage
WHO	World Health Organization

Chapter 1: Introduction

Since the end of the Second World War, international development has largely been synonymous with economic growth. A modern, holistic version of international development considers broader approaches to improve the lives people can lead by removing barriers, or "un-freedoms" rather than a limited concentration on expanding economic wealth. According to Amartya Sen, "among the most important freedoms that we can have is the freedom from avoidable ill-health and from escapable mortality" (Sen 1999). Global health, or collaborative trans-national research and action that promotes health for all, contributes to holistic development through numerous pathways (Beaglehole and Bonita 2010). Achievements such as the eradication of smallpox, drastic reduction in polio incidence, and widespread administration of HIV/AIDS therapeutics have afforded freedom from avoidable morbidity and mortality to millions around the world. Despite the undeniably positive impacts of disease-centered global health initiatives, true freedom from ill-health is only gained when populations have access to comprehensive health services that can address a range of potential health issues.

Global health priorities have long reflected the tension between meeting immediate health needs of populations and removing structural barriers that contribute to poor health. Scholars have identified shifting priorities throughout the history of global health as a "pendulum" swinging between vertical disease control initiatives and health systems strengthening approaches that aim to provide comprehensive preventive and curative care to communities (Uplekar and Raviglione 2007; Hafner and Shiffman 2013; Packard 2016). Health systems are comprised of the people, institutions, and resources that contribute to the production of health in a certain population.

When health systems are organized to ensure that everybody in a society has access to high-quality and acceptable health services they need and can use them without incurring excessive costs, the vision of Universal Health Coverage (UHC), freedom from ill-health is achieved. Achieving UHC is therefore the global health community's health-services oriented platform for promoting holistic development in the twenty first century.

While there is a clear global consensus on the importance of strengthening health systems to achieve UHC in low- and middle-income countries (LMICs), there is a lack of agreement on the exact definition of what UHC entails (O'Connell, Rasanathan, and Chopra 2014; Latko et al. 2011; Abiiro and De Allegri 2015). Broadly, achieving UHC is a multi-dimensional concept based in the legal right to health which encompasses health-related social security systems, financial protection, and access to quality health care according to need (Abiiro and De Allegri 2015). At the local level, health systems that achieve UHC provide equitable access to quality and affordable services that address the community's health needs. Measuring progress towards such a complex end-goal is difficult. Currently, UHC progress is tracked by two indicators: one that quantifies the extent of financial protection in a community, and one that measures the effective coverage of key health services (Hogan et al. 2018; Boerma, Eozenou, et al. 2014; Wagstaff et al. 2018; World Health Organization and World Bank 2015). For the latter measurement to be an appropriate indicator of health systems performance, the services provided must respond to the health needs of populations. Unfortunately, there is a major gap in the measurement of health system ability to prevent and manage non-communicable diseases (NCDs) in LMICs.

Over the past 50 years, the burden of disease in LMICs has shifted from acute conditions to NCDs and chronic illnesses (World Health Organization 2009). Despite accounting for over 31 million deaths in LMICs in 2019 (more than HIV, tuberculosis, and maternal deaths combined) NCDs have not yet been prioritized in the global health agenda (Zuccala and Horton 2020; World Health Organization 2019). Hypertension, or high blood pressure, is the leading risk factor for global cardiovascular mortality and morbidity, which causes a third of all deaths globally (The Global Burden of Metabolic Risk Factors for Chronic Diseases Collaboration 2014). Although there are relatively simple and cost-effective interventions for detecting and controlling high blood pressure at the primary health care level, progress towards successful hypertension management is not well conceptualized or tracked within the UHC monitoring framework, resulting in a de-prioritization of health system-level intervention for hypertension management.

Health systems and delivery strategies in LMICs designed to address the previously overwhelming burden of communicable diseases and maternal conditions are not optimally organized to deliver the continuous, complex, multi-sectoral, and sustained services required to prevent and manage chronic conditions, such as hypertension, over the life course (Martin 2007; C. D. Willis et al. 2013; Clarke et al. 2017; Goudge et al. 2009; Bhojani et al. 2014). To improve and track health system ability to deliver continuous care for chronic conditions, countries increasingly need tools to evaluate the performance of health systems and services delivery arrangements that influence the health of populations suffering from chronic diseases. Within the UHC measurement framework, effective coverage is the primary indicator for assessing performance related to health services delivery (Ng et al. 2014; World Health Organization and

World Bank 2017; Boerma, AbouZahr, et al. 2014). Effective coverage can be defined as the fraction of potential health gain actually delivered to a population in need, and is a widely accepted indicator for understanding a health system's capacity to deliver specific (or a package of) services (Ng et al. 2014; Hannah H Leslie et al. 2017; Jannati et al. 2018). Few studies have attempted to describe the concept of effective coverage in the context of hypertension management, and fewer still have done so in resource-constrained settings (López-López, Gutiérrez-Soria, and Idrovo 2012; Charoendee et al. 2018). Academics and the World Health Organization (WHO) alike have acknowledged the shortcomings in current measurement of effective coverage of chronic disease measurement services and have called for advances in these methods (Lozano and GBD 2019 Universal Health Coverage Collaborators 2020; Agyepong and Murray 2018; World Health Organization and World Bank 2017, 2019). Without appropriate methods for measuring effective coverage of services to manage chronic diseases, health systems performance for addressing NCDs cannot be adequately assessed or improved.

There is an urgent need to understand and address challenges associated with providing services to manage NCDs in LMICs. This thesis seeks to improve the evaluation of health systems performance in managing chronic diseases in a low-resource setting by improving the measurement of effective coverage of hypertension management in rural Bihar, India. The remaining sections in this chapter describe (i) the goals and potential impact of this research, (ii) the need for this research at the global level, (iii) the study site, Bihar, India, (iv) the contextualization of global challenges within the study site, (v) the study aims, (vi) the conceptual framework underpinning this research, (vii) the parent study and its design, and (viii) the outline for presenting the remainder of the dissertation.

Thesis Goals and Potential Impact

Quantifying health systems performance in terms of preventing and managing NCDs is a matter of immediate concern for governments and must be addressed with urgency. There is remarkably little information on methods to measure effective coverage of services to manage chronic conditions in LMICs. It is essential that advances are made in this field to identify and address service bottlenecks so that populations can access chronic disease management services. This thesis will inform improvements in population health by demonstrating how the application of an effective coverage framework can advance measurement of health system performance for NCD management.

The objective of this thesis is to improve measurement of health systems performance related to chronic disease management in a resource-constrained setting. The study first conducts a scoping literature review to develop a framework for measuring barriers to achieving effective coverage of services to manage hypertension in low-resource settings (called the expanded hypertension care cascade). This framework is then applied to quantify supply- and demand-side barriers along the pathway towards reaching effective coverage of these services in rural Bihar, India. Finally, a new index metric, informed by the largest identified bottlenecks, is developed to comprehensively assess the effective coverage of hypertension management services in rural Bihar and LMICs globally. The findings from this study can inform policy to improve global measurement of chronic disease management services and specifically to improve hypertension management in Bihar. The full research process can be applied to other chronic diseases and/or resource-limited settings to further improve chronic disease management.

Improved methodologies to measure effective coverage of chronic disease management services, including hypertension management, are desperately needed. This thesis will help address this need by proposing a framework for measuring effective coverage of hypertension management services. The expanded hypertension care cascade can be used to inform the design and data collection of future studies that measure hypertension burden in populations. The effective coverage index can be incorporated into future aggregate measures of effective coverage to more appropriately represent health system ability to manage hypertension. Specifically, incorporating the proposed index measure of effective coverage for hypertension management services into the UHC service coverage index would better reflect coverage of chronic disease management services than current measurements. Further, the methods described for developing the measurement framework for hypertension management can be adapted for other chronic diseases, such as diabetes, cancers, and mental illness. Applying the expanded hypertension care cascade and the effective coverage index to assess health system performance has implications for improving population health in LMIC settings.

Especially where resources are limited, it is essential for health systems to maximize the marginal benefit of each dollar spent on health. The application of the expanded hypertension care cascade helps public health officials in rural Bihar to quantify the largest systemic constraints (on both the supply- and demand-side) to achieving the effective coverage of hypertension management services. This analysis essentially allows policymakers in Bihar to prioritize interventions to improve hypertension management in the state. Finally, the effective coverage index will allow health officials to prioritize certain aspects of service delivery (e.g. expanding coverage or improving quality of services). Taken together, these studies will inform

a suite of interventions that can be used to improve hypertension management in rural Bihar. The methodology used to apply the framework and conduct this analysis can also be applied to other LMIC settings to identify options for improving hypertension management.

In summation, this thesis addresses gaps in existing methods to measure health systems' ability to provide services for NCD management in LMICs. It provides a new measurement framework (the expanded hypertension care cascade) for measuring effective coverage of hypertension management services, which can inform global discussions on NCD management that are pertinent to tracking and achieving UHC. A comprehensive index for measuring effective coverage of hypertension management services is also proposed to advance the methods available for monitoring health systems performance. The thesis applies the expanded hypertension care cascade and calculates effective coverage index for a low-resource health system (Bihar, India) to inform local policy to improve hypertension management services.

Measuring Effective Coverage for NCDs Globally

Effective coverage is a useful framework for assessing health system performance, and progress towards UHC, because it links the quality (effectiveness) of services delivered with the health outcomes achieved by a population, conditioned on the need for such services. The motivation for this thesis is not to improve measurement of effective coverage for the sake of effective coverage alone, but rather because the measure is a critical component of tracking UHC and making progress towards better health for all. This section provides necessary background information for understanding the relevance of this thesis to the global discussion on UHC and the role of the effective coverage framework in measuring health system performance related to

providing services to manage NCDs, specifically, hypertension. It also presents the challenges associated with current methods for measuring effective coverage of hypertension globally.

Universal Health Coverage

According to the WHO, achieving UHC means that all individuals and communities receive the health services they need without suffering financial hardship (World Health Organization n.d.). Progress towards UHC is generally conceptualized at the national level across three dimensions: i) expanding access of services to more of the population, ii) increasing the number and quality of services offered, and iii) reducing fees and cost sharing among the population (Kutzin 2013). It is generally the responsibility of the State to provide the leadership and governance necessary to achieve UHC at local levels, with the support of actors from non-government organizations (NGOs), the private sector, and the international development community. The importance of community empowerment and the role of community organizations in achieving UHC cannot be overstated: strong primary health care systems drive progress towards UHC. Fortunately, local communities are beginning to receive high-level national political support for UHC.

Building on previous initiatives like Health for All and the Alma-Ata Declaration, achieving UHC is becoming a focal point in global health policy, especially in LMICs. As of September 2015, all United Nations member states had committed to achieving UHC through the adoption of the Sustainable Development Goals (SDGs), especially the goal for inclusive health (Goal 3) by 2030 (United Nations 2015b). The largest globally coordinated effort to achieve UHC falls under the SDGs, particularly goal 3.8 which aims to "achieve universal health coverage, including financial risk protection, access to quality essential health-care services and access to

safe, effective, quality and affordable essential medicines and vaccines for all" by 2030 (United Nations 2015a). Recognizing shortcomings in their predecessors, the Millennium Development Goals (MDGs), the SDGs reflect progress that has been made in global health since 2000, including a growing focus on preventing and treating non-communicable diseases and improving the quality of health interventions rather than expanding coverage alone (Nugent et al. 2018; Kruk, Larson, and Twum-Danso 2016; Sobel, Huntington, and Temmerman 2016). In 2019, world leaders adopted a high-level United Nations Political Declaration on UHC, furthering their commitments to accelerate progress towards UHC. Towards this end, studies have shown that at least 75 countries have implemented legal frameworks and systems for UHC (Feigl and Ding 2013). These frameworks are the necessary underpinnings of the systemic reforms required to achieve UHC in a country.

Reaching UHC requires intervention across the health system. A health system consists of all the organizations, institutions, resources, and people whose primary purpose is to improve health (World Health Organization 2007). Organizing or strengthening health systems to achieve UHC is an overarching goal, as this contributes to resilience, enabling societies to adapt to emerging health threats, such as non-communicable diseases (NCDs) or pandemics (Kruk et al. 2015). The coronavirus disease (COVID-19) pandemic has intensified efforts to build resilient health systems that are responsive to local needs and resistant to external shocks. Accordingly, within national health systems, comprehensive primary health systems are generally seen as the catalyst for achieving progress towards UHC. This is due in part to the fact that around 90% of all health needs can be met at the primary health care level (Doherty and Govender 2004). However, comprehensive primary health goes beyond providing clinical care. It also involves addressing

social determinants of health, changing contexts to positively influence behavioral determinants of health, and promoting primary prevention and care, including counseling and education (Frieden 2010). Common barriers to achieving UHC span the components of the health systems building blocks (World Health Organization 2007). Inadequate basic infrastructure, insufficient and maldistributed human resources, poor quality health services, shortages of essential medicines and health products, a lack of local participation, insufficient health information systems, and ineffective financing often plague LMICs attempting to achieve UHC. With the large number of system components involved in achieving UHC, measuring progress is a complex task.

Unlike disease-focused global public health initiatives such as eradicating polio, no simple indicator exists for monitoring progress towards UHC. Vertical programs often serve as the bedrock for providing essential health services (e.g. polio and child immunization platforms), however achieving UHC requires comprehensive, system-wide action. Five years into the SDG era, there remains confusion on how to measure health system progress towards achieving universal coverage of key health services, including hypertension management. The UHC monitoring framework within the SDG declaration is a useful starting place for understanding how UHC is conceptualized by global experts. Two indicators were adopted by the UN Statistical commission in 2017 to monitor progress towards UHC: i) achieving coverage of essential health services (indicator 3.8.1) and ii) ensuring financial protection against excessive health expenditure in countries (indicator 3.8.2).

The first indicator is a composite index which aims to demonstrate both the quality and coverage of a representative range of essential services from across the health system. Tracer indicators indicating the effective coverage of four categories (reproductive, maternal, newborn, and child health; infectious disease control; non-communicable disease control; and service capacity) were selected based on standardized criteria (Boerma, AbouZahr, et al. 2014). [1] When combined, these contribute to an index that demonstrates progress towards providing the basic services deemed necessary under UHC (Table 1.1). Scores for each indicator are calculated from the relevant household surveys, administrative systems, and surveillance systems available in each country. The index is calculated by taking the geometric mean across indicators within each of the four categories and then taking the geometric mean of the four overall category means to obtain the final service coverage index (Hogan et al. 2018). The resulting index is reported on a range from 0-100, with 100 being the maximum (and ideal) score. The effective service coverage index has been calculated for 183 countries as a baseline in 2015, in 2017, in 2019, and retroactively using available data for 1990 and 2000 (Hogan et al. 2018; World Health Organization and World Bank 2019; Lozano and GBD 2019 Universal Health Coverage Collaborators 2020).

[1] These selection criteria include epidemiological relevance, whether the intervention is proven to be cost-effective, measurability of numerators and denominators, existence of a clear target, whether disaggregation is possible for equity considerations, quality of intervention, whether the indicator can be compared, ease of communication, data availability, inclusion in international initiatives, and parsimony

Table 1.1: Indicators for tracking essential service coverage in SDG 3.8.1

Domain	Tracer Area	Tracer Indicator	Type	Rationale, Limitations, and possible refinements
Reproductive, maternal, newborn, and child health	Family planning	Percentage of women of reproductive age (15–49 years) who are married or in-union who have their need for family planning satisfied with modern methods	Effective service coverage	Demand satisfied with a modern method is SDG indicator 3.7.1. However, it has a relatively complex denominator derived from multiple survey questions, and data collection often focuses on women in unions, as opposed to all sexually active women.
	Pregnancy and delivery care	Percentage of women aged 15-49 years with a live birth in a given time period who received antenatal care four or more times	Service coverage	The number of antenatal care visits captures the amount of contact with the health-care system but does not capture quality of care received and might not lead to a reduction in mortality. Skilled attendance at birth (SDG indicator 3.1.2) is a preferred alternative; however insufficient standardized measurement of skilled health-care personnel makes cross-country comparisons difficult. Efforts to improve reporting on SDG 3.1.2 should resolve these comparability issues and allow 3.1.2 to replace four or more visits to antenatal care in the index.
	Child immunization	Percent of children aged 1 year who have received three doses of a diphtheria, tetanus, and pertussis vaccine	Service coverage	Three doses of diphtheria, tetanus, and pertussis vaccine, which is identical to coverage with pentavalent vaccine in most countries, is an indicator of routine infant immunization system. However, several other vaccines, such as those for measles (second dose), pneumococcal pneumonia, and rotavirus diarrhea, typically have lower coverage and the fraction of children receiving all vaccines in a national schedule is typically much lower (although not possible to measure directly with existing data systems in most countries). Once metadata for SDG 3.b.1 are defined, an indicator consistent with 3.b.1 could be used in the index in place of the diphtheria, tetanus, and pertussis vaccine measure.
	Child treatment	Percentage of children under 5 years of age with suspected pneumonia (cough and difficult breathing not due to a problem in the chest and a blocked nose) in the two weeks preceding the survey taken to an appropriate health facility or provider	Service coverage	Pneumonia is a leading cause of child illness and death. Suspected pneumonia is identified on the basis of a series of survey questions about illnesses in the past 2 weeks, which might include mild respiratory illnesses. However, the indicator does not currently capture the quality of care received as a mother's recall of treatment specifics can be poor. The main alternative indicator for child treatment that is widely measured is use of oral rehydration solution therapy for child diarrhea, which is also a leading cause of child death. The inclusion of the sanitation indicator in the index is relevant for diarrhea prevention.
Infectious Diseases	Tuberculosis treatment	Percentage of incidence tuberculosis (TB) cases that are detected and success- fully treated in a given year	Effective service coverage	This indicator combines two more common ones—the rates of case detection and of treatment success—to estimate the proportion of all people with tuberculosis who successfully complete treatment. Calculation of the case detection rate requires estimates of incident cases (including those not identified by the health-care system). Treatment success is measured through administrative data, and includes all patients who successfully completed treatment without bacteriological evidence of treatment failure.
	HIV treatment	Percentage of people living with HIV currently receiving antiretroviral therapy (ART)	Service coverage	Provision of antiretroviral therapy averts a substantial number of deaths in high-burden HIV countries and can be a marker of how well a health system reaches marginalized populations with higher HIV prevalence in countries with lower HIV burden. Recent surveys have begun to measure effective coverage of antiretroviral therapy by obtaining data on viral load suppression. The numerator— people taking antiretroviral therapy—is generally obtained from health facility data, whereas the denominator is estimated from HIV epidemiological data.
	Malaria prevention	Percentage of population in malaria-endemic areas who slept under an insecticide-treated bed net (ITN) the previous night	Service coverage	Insecticide-treated bed net distribution is a major program in malaria-endemic countries. Coverage estimates should account for geographical heterogeneity in malaria risk when analyzing national household surveys. Because the nets deteriorate over time, effective coverage can decline without resupply.
	Water and sanitation	Percentage of households using at least basic sanitation facilities	Service coverage	Although access to clean water and safely managed sanitation are not always implemented by the health sector, these interventions are important to public health. The current indicator of at least basic sanitation typically has lower coverage than access to at least a basic water source, and therefore is used as the tracer indicator for this area. This tracer indicator could be replaced with SDG 6.1.1 or 6.2.1 once they are more widely reported.
Non-Communicable Diseases	Prevention of cardiovascular disease	Age-standardized prevalence of non-raised blood	Proxy	Hypertension is the leading risk factor for cardiovascular disease. The prevalence of normal blood pressure is the sum of the percentage of individuals who do not have hypertension and the percentage of individuals whose

Domain	Tracer Area	Tracer Indicator	Type	Rationale, Limitations, and possible refinements
		pressure among adults aged 18 and older, regardless of treatment status		hypertension is controlled by medication. The absence of hypertension is a result of prevention efforts via promotion of physical activity and healthy diets, and other factors. Hypertension controlled with medication is a result of effective treatment. This indicator is therefore a proxy for both effective health promotion and effective medical services. This indicator will be replaced with treatment coverage in people with hypertension once data become available.
	Management of diabetes	Age-standardized mean fasting plasma glucose for adults aged 18 years and older	Proxy	Mean fasting plasma glucose can be reduced through effective treatment of individuals with diabetes and through diabetes prevention with effective promotion of protective behaviors and diets. However, diabetes treatment guidelines do not recommend lowering blood glucose to non-diabetic concentrations for all patients, meaning that a population with a high prevalence of diabetes should not necessarily attain a low mean fasting plasma glucose. This indicator will be replaced with the proportion of people with diabetes receiving treatment once data become available.
	Cancer detection and treatment	Percent of women aged 30-49 years who have received cervical cancer screening	Service coverage	Data on this indicator are obtained in some household surveys, although these data are not yet available widely enough to be used for global monitoring. The indicator does not reflect whether effective treatment is available. This indicator was chosen over other potential cancer screening indicators, such as for breast or prostate cancer, because of clearer guidelines for cervical cancer, and because cervical cancer screening is the only cancer screening indicator included in the core indicator set of the non-communicable diseases global monitoring framework.
	Tobacco control	Age-standardized prevalence of adults aged 15 years and older not smoking tobacco in last 30 days	Proxy	Prevalence of smoking (SDG indicator 3.a.1) is a proxy for adoption and enforcement of effective anti-tobacco measures. This indicator could be replaced with an indicator of implementation of tobacco control measures.
Service Capacity and Access	Hospital access	Hospital beds per capita, relative to a maximum threshold of 18 per 10,000 population	Proxy	This indicator is a proxy for access to essential inpatient services. It has more data available in low-income and middle-income countries than number of inpatient hospital admissions, with which it is highly correlated (ρ=0·84 in low-income and middle-income countries). A threshold is used to capture only low capacity levels because high values might represent overcapacity or inefficient allocation of resources.
	Health- care worker density	Health professionals (physicians, psychiatrists and surgeons) per capita, relative to maximum thresholds for each cadre	Proxy	Comparable data on patient use of outpatient facilities are not readily available in low-income and middle-income countries. Physician density, part of SDG indicator 3.c.1, is included as a proxy for access to outpatient services that are not captured by tracer indicators included elsewhere in the index. Nurses and midwives are currently excluded because of limited comparability between countries in existing global databases. The density of psychiatrists is a proxy for availability of mental health services, and surgeon density is a proxy for access to surgical and emergency care. As with hospital beds per capita, a threshold is used to capture low densities for all three cadres.
	Access to essential medicines	Proportion of health facilities with availability of the WHO-recommended core list of essential medicines	Proxy	Medicines are the main intervention resulting from clinical services, and their availability provides a proxy for access to services beyond mere contacts with professionals. This tracer will be included once data become widely available.
	Health security	International Health Regulations (IHR) core capacity index, which is the average percentage of attributes of 13 core capacities that have been attained at a specific point in time	Proxy	Because many health risks are rare, preparedness must be measured to capture health security. This indicator—SDG 3.d.1—is currently based on key informant reports to WHO, but could be informed by Joint External Evaluations in the future.

The second indicator measures the incidence of financial hardship caused by health payments, also known as catastrophic health expenditure. The official indicator calculates the proportion of households in a country with large expenditures on health (greater than either 10% or 25%) as a share of total household consumption or income. Initial studies have reported that the global

incidence of catastrophic health spending at the 10% threshold has increased from 9.7% in 2000 to 11.7% in 2010 (Wagstaff et al. 2018). Although financial protection is an important metric of health system performance, this thesis primarily focuses on the first component of UHC, effective service coverage.

The aforementioned service coverage index is not a definitive list of the services that must be included within systems that have achieved UHC, nor is it the only way to track service coverage for UHC. However, the service coverage index has been adopted by the SDG monitoring group, by WHO, and by the World Bank, ensuring that it is the primary way that progress towards UHC is measured globally. As such, each tracer indicator within the service coverage index should reflect progress towards ensuring coverage of the basic services that have the largest impact on improving health. The WHO acknowledges that while all of the indicators in the service coverage index should ideally reflect effective coverage, for many health areas, indicators of effective coverage are not available either "due to lack of investment in data collection or difficulties around defining an operational indicator for a particular health service" (World Health Organization and World Bank 2017). In cases where indicators for effective coverage are not used, the index relies on service coverage indicators and proxy indicators. Service coverage, or contact coverage, indicators are those which describe the percent of individuals in need of a service who receive that service, but do not account for the quality of the service. Proxy indicators are upstream or downstream services correlated with the provision of health services to those in need. Service coverage or proxy indicators are used to track NCDs, mental health, and routine health examinations in the official SDG 3.8.1, presenting problems for measuring health system performance. Without incorporating a measure of quality, service coverage is only

weakly linked to the health benefits received by a population (Amouzou et al. 2019). Proxy indicators are further removed from the population's health benefits. Therefore, effective coverage, rather than service coverage, of essential health services is the preferred metric for tracking progress towards UHC. The lack of effective coverage metrics currently being used to calculate coverage of hypertension and other NCD management services within the UHC monitoring framework represents a major gap between the methods used to track health system performance and the services actually needed by populations.

Effective Coverage and Chronic Diseases

Effective coverage is a promising metric for evaluating program and health system success because it captures whether individuals are experiencing the improvements in health that are possible from medical and behavioral interventions. For this reason, the service coverage tracer indicators for monitoring progress towards UHC were designed to ideally capture effective coverage of specific interventions (Ng et al. 2014). Calculating effective coverage is based on a framework that incorporates three dimensions: (i) **need**: the proportion of a population in need of an intervention; (ii) **use**: the proportion of those in need who receive (and use) the service; and (iii) **quality**: the proportion of those receiving a service that is capable of resulting in the desired health benefit (Shengelia et al. 2005; Tanahashi 1978). Its calculation is often represented through the following equation:

$$\textit{Effective Coverage} = \textit{Utilization X Quality} \mid \textit{Need} = 1$$

Where utilization takes a value of either 0 or 1 (1 representing an individual in need who receives a service), quality takes a value between 0 and 1 based on intervention effectiveness (1

representing optimally effective services), and need takes a value of either 0 or 1 (1 representing an individual in need of a service). Hence, effective coverage can range from 0 to 1 at the individual level, depending largely on the quality of the service provided. Effective coverage can be aggregated across individuals to derive estimates for population groups and/or geographic areas, and can be aggregated across multiple interventions to reflect overall health system performance (Shengelia et al. 2005). Without the quality adjustment, the calculation reflects a simple service coverage estimate of an intervention, therefore the effective coverage metric is often interchangeably described as "quality-adjusted coverage". Studies have demonstrated large gaps between the crude and quality-adjusted coverage of reproductive, maternal, and child health services, ranging from 10 to 38 percentage points (Amouzou et al. 2019). This means that even if an intervention achieved 100% service coverage, only 62 to 90% of individuals received health services of sufficient quality to improve health. This result highlights the importance of striving to measure effective coverage of health services that lead to improvements in population health, rather than the crude coverage of health services. Such measurements require considerations of service quality and often entail linking household- and facility-based surveys to understand the impacts of quality of care on health outcomes (Munos et al. 2018). While these studies are being conducted with more frequency for interventions related to improving maternal and child health, no such study has yet been conducted to explore quality-adjusted care for chronic diseases. This shift from measuring service coverage to effective coverage must occur for high burden diseases across all contexts.

Combining the reach of health services with population health gains makes the effective coverage framework a parsimonious measurement tool for assessing health systems

performance. However, few studies have attempted to describe the entire effective coverage framework (i.e. need for services, use of services, and quality of services) in the context of chronic disease management, and fewer still have done so in resource-constrained settings. Whereas others have measured effective coverage for acute conditions, or for screening services for chronic diseases, measuring dimensions of effective coverage for the ongoing management of a chronic diseases is not well conceptualized or measured (Charoendee et al. 2018; López-López, Gutiérrez-Soria, and Idrovo 2012). This is a significant shortcoming due to the epidemiological differences between maternal and child health conditions and chronic diseases. Efforts to improve infant and child survival primarily rely on discrete points of contact between individuals and health systems to achieve health gains (e.g. four ANC visits during pregnancy, delivering a child at a health facility, or three visits for a full schedule of DTP immunization). Conversely, effective treatment for chronic diseases requires consistent monitoring, management, and developing relationships between patients and providers over a long time horizon. Examining the three components of effective coverage (need, use, and quality) in the context of chronic disease management demonstrates potential complications for applying the framework to such diseases and underscores the need for further research in this field.

According to the framework proposed by Shengelia et al., effective coverage can be defined as a product of service use and quality (effectiveness), conditioned on need for that service (Shengelia et al. 2005). Defining a need for services is an often-overlooked component of measuring effective coverage, however it has important implications for effective coverage calculations, as the number of individuals in need constitutes the denominator used to assess the percent of population reached. In his seminal paper, Bradshaw described a taxonomy of need,

which included; (i) normative need, which the expert defines as need in a given situation; (ii) felt need, which is equated with want; (iii) expressed need, which is defined as those people who demand a service; and (iv) comparative need, which studies characteristics of the population receiving a service and if there are people with similar characteristics not receiving a service, then they are in need (Bradshaw 1972). In the context of certain chronic diseases, such as mental illnesses or chronic lung disease, individuals may not be aware that they have a health problem. In this case, while the individual may have a normative need for mental health or chronic respiratory disease management services, she likely cannot want for nor demand these services. These examples demonstrate the finding that service coverage, and therefore effective coverage, conditioned on actual need can be less than any coverage measure conditioned on perceived need (Shengelia et al. 2005). Furthermore, felt or expressed need for services can vary over time with recurring or progressive chronic diseases, meaning that the same individual can be classified as in need or not in need of a variety of services depending on when their need is assessed. An individual with undiagnosed diabetes has completely different health service requirements than an individual with later-stage diabetes (i.e. the first individual requires screening and diagnosis, the second individual requires treatment). This example of shifting definitions of need represents a stark difference when compared to defining need for effective coverage of services like receiving a full schedule of DTP immunization (every one-year old child needs 3 doses) or receiving antenatal care (every pregnant mother needs 4 visits). Therefore, defining the need for services is complicated by the duration and nature of chronic diseases versus the relatively straightforward needs of users of maternal and child health services.

Utilization of chronic disease management services has several dimensions. Patient-provider interactions can take many forms, including screening, diagnosis, initial care planning, periodic check-ups (and treatment adjustments), and disease management. Yet another dimension of utilization is adherence to treatment and self-management over time, which are vital components of chronic disease management (Barr et al. 2003; Lall et al. 2018). Systematic reviews have identified barriers to adherence and interventions to improve medication adherence in high income settings, but there is limited evidence available in LMICs (Conn et al. 2015; Dennis et al. 2011). In LMICs, access to health services, especially those to manage NCDs, is generally low, resulting in low service utilization (O'Donnell 2007). Previous authors have described a typology of access, encompassing availability, accessibility, affordability, and acceptability of services (Penchansky and Thomas 1981). Others have since expanded on these typologies to identify various supply- and demand-side barriers associated with each of these access-related domains (D. H. Peters et al. 2008; Jacobs et al. 2012). These barriers to access can each play a role in preventing individuals from receiving the chronic disease management services they need. For example, stockouts may inhibit the availability of chronic disease medications, long distances to health facilities with dialysis equipment reduce accessibility of treatment for kidney failure, prices of medicines may be prohibitive for patients to adhere to treatment, and services may not be acceptable to people if they are not educated about chronic diseases or if treatments are culturally inappropriate. The concept of service utilization needs to be further considered in the context of chronic diseases, where service provision is not a one-time event, and often requires action from the patient long after an interaction with a provider.

Those receiving chronic disease management services may not achieve the desired health benefits of treatment if the quality of care is substandard. Quality of care has been defined by Donabedian as having three interrelated components; structure, process, and outcomes (Box 1.1) (Donabedian 1966, 1988). Donabedian argues that these three components of quality build on each other. In other words good structure increases the likelihood of good process, which in turn increases the likelihood of a good outcome (Donabedian 1988). He continues to note that while structural quality is furthest removed from health gains, neither the measurement of process nor the measurement of outcomes is superior for indicating service quality, and rather suggests that there are benefits to measuring both constructs depending on the needs of the study (Donabedian 1988). In the context of effective coverage, quality is generally equated to the effectiveness of an intervention (Shengelia et al. 2005). In most cases, measures of outcome quality, or health status, are incorporated as the quality dimension of effective coverage metrics (e.g. the proportion of tuberculosis cases that are successfully treated). Some chronic diseases can never be cured or can reemerge after remission, so outcome measures of quality may vary over time along with an individual's health status. When quality cannot easily be equated to the effectiveness of an intervention, standards to which quality is compared should be contextually relevant. In other words, when outcome quality cannot be measured, structure and process quality should be compared to locally-defined best practices to assess whether best practices were followed in providing care. This can complicate efforts to define measures of quality across various settings.

Box 1.1: Dimensions of Quality According to Donabedian

Structure – attributes of the setting in which care occurs, including:

- Material resources (e.g. facilities, equipment, and money)
- Human resources (e.g. number and qualifications of personnel)
- Organizational structure (e.g. medical staff organization, methods of reimbursement)

Process – what is actually done in giving and receiving care, including:

- Patient's activities in seeking care and carrying it out (e.g. adherence)
- Provider's activities in making a diagnosis and recommending or implementing treatment

Outcome – the effects of care on the health status of patients and populations, including

- Health benefits accrued by the patient
- Improvements in patient's knowledge and changes in behavior
- Patient's satisfaction with care

There are several challenges and complications associated with measuring the individual aspects of effective coverage of services to manage chronic diseases. Effective coverage of chronic disease management services in LMICs is largely understudied, yet requires immediate attention in order to appropriately monitor progress towards reaching UHC. Due to its global prevalence, severe economic impact on society, ability to be managed as a chronic disease at the primary care level, and lack of a current measure of effective coverage, hypertension is a key chronic condition that requires additional research. This thesis will explore issues in measuring effective coverage for hypertension management services to improve monitoring of health systems performance and progress towards UHC.

Hypertension and Effective Coverage

Hypertension, or high/raised blood pressure, is a common condition in which the long-term force of blood pushing against artery walls is high enough that it may eventually cause health problems, especially cardiovascular disease. It is estimated that some 1.4 billion people globally

are living with hypertension, including 1.0 billion hypertensive individuals living in LMICs (Mills et al. 2016). High blood pressure is a complex phenomenon influenced by individual behavior, nutrition, and environments throughout the life course. Factors that can influence blood pressure levels include fetal and early childhood nutrition (Victora et al. 2008), obesity (Institute of Medicine (US) 2010), sodium and potassium consumption (Sacks and Campos 2010; Du et al. 2014; He, Pombo-Rodrigues, and Macgregor 2014), illicit drug and/or alcohol use (Taylor et al. 2009), smoking (Virdis et al. 2010), physical activity (Institute of Medicine (US) 2010), air pollution (Liang et al. 2014), lead exposure (Navas-Acien et al. 2008), excessive noise (van Kempen and Babisch 2012), prolonged stress, and the use of blood pressure lowering medication (U. O. Andersen and Jensen 2010; Ezzati et al. 2015). Chronic hypertension can harden arteries, decreasing the flow of blood and oxygen to the body's essential organs, especially the heart, and can contribute to complications such as chest pain (angina), heart attack, and/or heart failure. It is the leading risk factor for global cardiovascular mortality and morbidity, resulting in 9.8 million deaths in LMICs per year, and also significantly increases the risks of stroke, kidney failure, and other diseases (World Health Organization 2019). Hypertension cannot be cured, but it can be managed and controlled with lifestyle modifications and medical treatment. Fortunately, a slight reduction in systolic blood pressure (5 mm Hg) has been associated with lower likelihoods of mortality, including reductions of 14% from stroke, 9% from heart disease, and 7% from all causes (Whelton et al. 2002). Starting treatment is conditional on the identification of hypertension, which varies based on the definition used by a clinician.

There are many guidelines for defining hypertension, however, individuals are generally diagnosed by comparing multiple measures of systolic (pressure during contraction of heart

muscle) and diastolic (pressure when heart muscle is between beats) blood pressure to a set target for a population subgroup (Table 1.2). Physician use of these guidelines varies: in India, for example, 63.85% of physicians used guidelines established by the Joint National Committee (JNC8), 14.23% referred to Indian Guidelines on Hypertension, 8.46% followed more than one guideline, and 6.93% used their own approach (Hiremath et al. 2016). Studies have demonstrated the significant impact of using various blood pressure control guidelines on hypertension management. In Iran, the prevalence of hypertension was sharply increased from 29.9% to 53.7% of the population over age 25 when switching from the JNC8 guidelines (140/90 mmHg) to the 2017 ACC/AHA (130/80 mmHg) guidelines (Mahdavi et al. 2020). The same study found that the percent of population previously diagnosed as hypertensive that had achieved control decreased by over one half, falling from 39.1% under JNC8 guidelines to 19.6% under 2017 ACC/AHA guidelines (Mahdavi et al. 2020). Explicitly choosing a standard guideline is essential in order to set targets for blood pressure management in a particular population. Regardless of hypertension definition, over time, hypertension prevalence has shifted from primarily high-income countries to LMICs, causing massive morbidity, mortality, and economic losses.

Table 1.2: Common guidelines for defining hypertension

Parameter	**ACC/AHA (2017)** (Whelton et al. 2018)	**ESC/ESH (2018)** (Williams et al. 2018)	**JNC 8 (2014)** (James et al. 2014)	**ISH (2020)** (Unger et al. 2020)	**IGH IV (2019)** (Shah and Association of Physicians of India 2019)
Definition of hypertension (mm Hg)	≥130/80	≥140/90	≥140/90	≥140/90	≥140/90
Grading of normal pressure (mm Hg)	Normal: <120/80 Elevated: 120-129/<80	Optimal: <120/80 Normal: 120-129/80-84 High Normal: 130-139/85-89	Normal: <120/80 Prehypertension: 120-139/80-89	Normal: <130/85 High Normal: 130-139/85-89	Optimal: <120/80 Normal: 120-129/80-84
Hypertension Stages (mm Hg)	Stage 1: ≥130-139/80-89 Stage 2: ≥140/90	Grade 1: 140-159/90-99 Grade 2: 160-179/100-109 Grade 3: ≥180/110	Stage 1: 140-159/90-99 Stage 2: ≥160/100	Grade 1: 140-159/90-99 Grade 2: 160-179/100-109 Grade 3: ≥180/110	Stage 1: 140/159/90-99 Stage 2: 160-179/100-109 Stage 3: ≥180/110
Age Specific Blood Pressure targets (mm Hg)	<65 years: <130/80 ≥65 years: <130/80	<65 years: <120-129/70-79 ≥65 years <130-139/70-79	<60 years: <140/90 ≥60 years: <150/90		<65 years: 130-140/70-80 ≥65 years: 130-140/70-80

Legend: ACC= American College of Cardiology; AHA = American Heart Association; ESC = European Society of Cardiology; ESH = European Society of Hypertension; IGH = Indian Guidelines on Hypertension; ISH = International Society of Hypertension Global Practice Guidelines; JNC 8 = Eighth Joint National Committee

From 2000 to 2010, the age-standardized prevalence of hypertension decreased by 2.6% in high-income countries but increased by 7.7% in LMICs (Mills et al. 2016). Today, the majority of the global NCD burden is felt in LMICs, where people on average develop hypertension at a

younger age (40-59 years old) than in high-income countries (60 and older) (Zhou et al. 2017; Sarki et al. 2015). Within LMICs, hypertension prevalence does not always significantly vary across income groups, however wealthier populations are more likely to be aware of their condition and be receiving treatment than poorer groups (Palafox et al. 2016). In addition to health services not reaching the poor in LMICs, the cost of continued treatment is prohibitive for up to 31% of households in low-income countries (Attaei et al. 2017). A review of the cost of medical hypertension treatment found that the average monthly cost of hypertension management in LMICs is US$22 (Gheorghe et al. 2018). This equates to 38% of the monthly income for those living at or below the $1.90-per-day international poverty line, 23% of income for those living at or below the $3.20 poverty line for lower-middle-income countries, and 13% of income for those living at or below the $5.50 poverty line for upper-middle-income countries. Therefore, in all low- and middle-income countries, the average cost of managing hypertension therefore qualifies as catastrophic health expenditure (at the 10% level) for individuals living at or below the poverty line. Thus, hypertension is a common chronic condition contributing to major disease burden and its management can cause massive economic losses in resource-constrained settings. Improvements in the effectiveness and efficiency of hypertension management in LMICs can save lives and contribute to the financial protection of vulnerable people.

Unlike some other chronic conditions which require more advanced procedures to diagnose and treat, hypertension diagnosis and management does not require significant resources. Blood pressure can be measured, hypertension can be diagnosed, and treatment can be initiated at low cost in the primary care setting by both doctors and non-physician health workers (World Health

Organization 2010). The WHO recommends lifestyle changes to prevent the development and progression of hypertension, followed by pharmacologic therapy (World Health Organization. 2016). Evidence-based lifestyle changes to lower blood pressure include improving diet (particularly by reducing sodium intake), increasing exercise, losing weight, stopping smoking, and reducing alcohol consumption and these changes can lower blood pressure between 3-11/2.5-5.5 mm Hg depending on the intervention (Oza and Garcellano 2015; Saseen et al. 2005). Following, or in tandem with lifestyle changes, there are a range of drug therapies and guidelines for their use in lowering blood pressure in various clinical settings and patient conditions. These guidelines are often country-specific and based on availability of drugs, thus consideration of context is essential, especially when measuring need for and relative quality of hypertension management services.

Resource-constrained countries facing a rising burden of hypertension increasingly need tools that can measure health system performance in improving the health of those suffering from high blood pressure. Within the current UHC monitoring index, global progress towards improved hypertension management is measured by national rates of "Age standardized prevalence of non-raised blood pressure (systolic blood pressure < 140 mm Hg and diastolic blood pressure < 90 mm Hg) among adults aged 18 years and older" (World Health Organization and World Bank 2019). This indicator is classified as a proxy of effective medical services to manage hypertension and its shortcomings as a measure of hypertension management are widely acknowledged (World Health Organization and World Bank 2015, 2017, 2019). Although proxy indicators are supposed to be positively correlated with downstream measures of coverage, in low- and lower-middle income countries, the prevalence of non-raised blood pressure in adults

has a weak negative relationship with service and effective service coverage (Figure 1.1). The WHO and World Bank have acknowledged the shortcomings of this indicator in each of the global monitoring reports on UHC and have also indicated their ideal replacement indicator (Table 1.3). The current indicator will be replaced by a service coverage indicator (percent of hypertensive individuals receiving treatment) once sufficient data is available (World Health Organization and World Bank 2017). Even once the proposed hypertension treatment coverage indicator is adopted, since service quality is not incorporated, it will not be a measure of effective coverage. As previously noted, without accounting for the quality of health services, the coverage of treatment services is not closely associated with population health gains (Amouzou et al. 2019). Therefore, additional research must be done to advance understandings of methodologies for measuring effective coverage of hypertension management services.

Figure 1.1: Association between non-raised blood pressure and hypertension treatment and quality-adjusted treatment

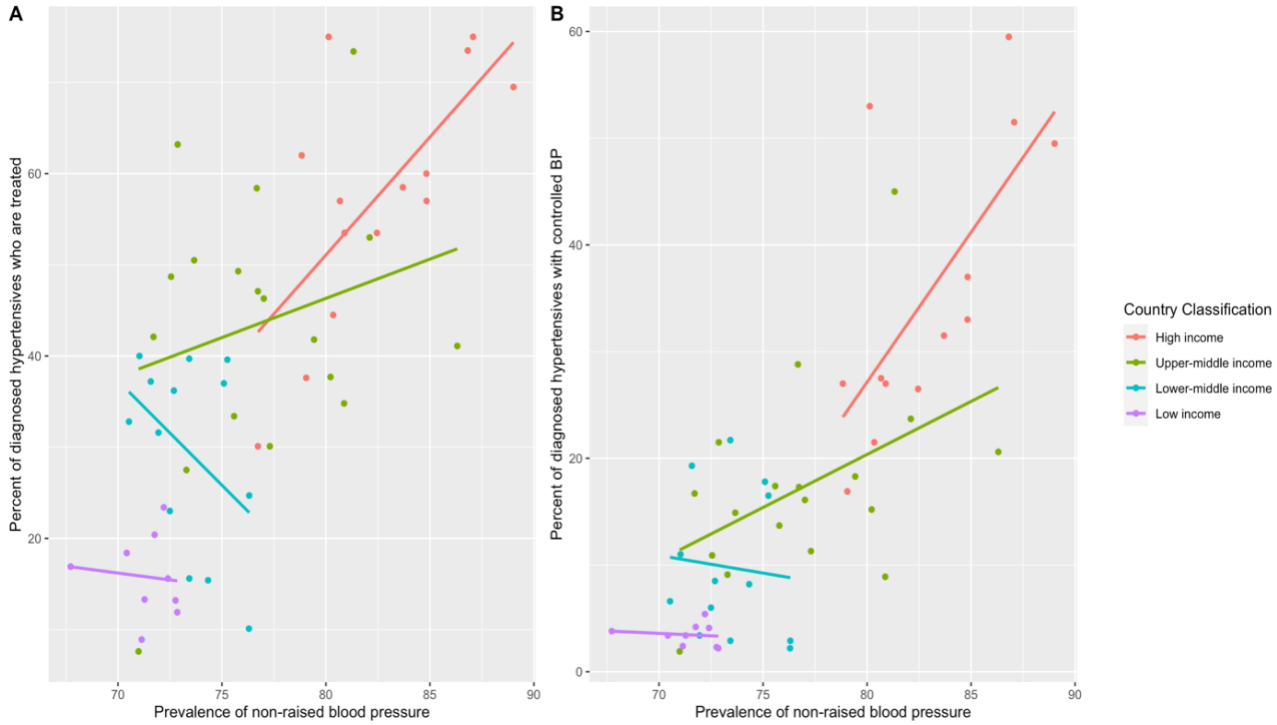


Table 1.3: Evolution of measuring effective coverage of hypertension management services

Document	Year	Tracer Indicator	Discussion on Indicator	Cascade of Care
Tracking Universal Health Coverage: First Global Monitoring Report	2015	(*Proposed but not adopted*): Adults 18 years and older currently taking antihypertensive medication / Adults 18 years and older taking medication for hypertension, with systolic blood pressure ≥ 140 mmHg, or with diastolic blood pressure ≥ 90 mmHg	Defines the indicator as a treatment coverage indicator. Defines effective coverage as the proportion of people on blood pressure medication with blood pressure below 140/90	Recognized in the context of HIV effective coverage. States that "in cases where the end-point of the effective coverage cascade cannot be measured, earlier steps along the cascade must serve as proxies"
Tracking Universal Health Coverage: 2017 Global Monitoring Report	2017	Prevalence of normal blood pressure, regardless of treatment status (%)	Acknowledges the indicator as a proxy for both effective health promotion and effective medical services. States that the indicator will be replaced with a measure of treatment coverage among people with hypertension, once the data become available.	N/A
Primary Health Care on the Road to Universal Health Coverage: 2019 Monitoring Report	2019	Age-standardized prevalence of non-raised blood pressure (systolic blood pressure < 140 mm Hg and diastolic blood pressure < 90 mm Hg) among adults aged 18 years and older	Recognizes that the age-standardized prevalence of blood pressure is not a good predictor of treatment coverage and effective coverage in LMIC. States that measuring treatment and control to assess effective coverage is "relatively straightforward" for hypertension	Endorses care cascades as tools for measuring quality of care which start from the number of people in need and include the successive steps of seeking care, receiving appropriate care (quality of care), controlling or preventing disease, and survival and well-being. Calls for quality measures that determine whether guidelines or standard operating procedures were followed.

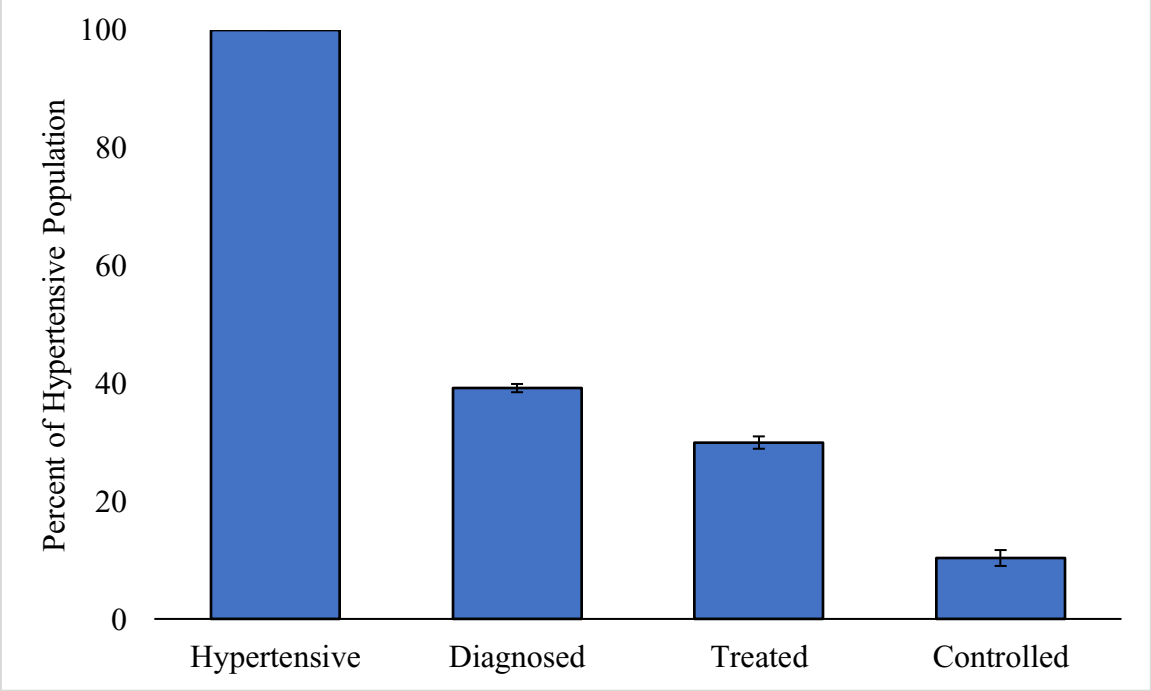
There are several aspects related to the epidemiology of hypertension and the current conceptualization of effective coverage that complicate the measurement of effective coverage for hypertension management services. Primarily, hypertension is representative of the dynamic and time-varying nature of chronic diseases which has not been accounted for in effective coverage measurement. While an individual who is formally diagnosed with high blood pressure will always be considered to be hypertensive, with effective treatment and lifestyle changes, blood pressure can be lowered to normal levels that reduce additional risk of adverse health effects associated with hypertension. Over time, the health services required by a hypertensive patient vary: from education and awareness in pre-hypertensive patients to screening and diagnosis to detect hypertension in its early stages, to treatment and management advice over the rest of the life course. Thus, the definition of the services needed within the broader effective coverage metric varies over the course of managing an individual patient's hypertension. The guidelines for classifying individuals as hypertensive influence not only the need for services, but also the quality of services when using health outcomes as a quality metric (i.e. when high blood pressure has been effectively controlled). Once a patient is diagnosed with hypertension and linked to treatment, in many cases, finding an effective combination of drug therapy and lifestyle advice requires several iterations and interactions with providers before blood pressure is lowered to healthy levels (Calhoun et al. 2008). Even if a patient is prescribed with a treatment regimen that could lower blood pressure, if adherence to treatment is inconsistent, then blood pressure status can fluctuate between normal and high levels over time. Thus, both patient- and provider-side characteristics of hypertension management must be considered in order for services to be classified as "used" if they are to result in health gains for a patient. Finally, defining what constitutes "quality" services in hypertension management is complex. Measuring whether a hypertensive individual is normotensive at a certain

time point indicates some level of outcome quality, however the same individual's blood pressure may fluctuate over time, resulting in different indications of quality depending on when the measurement is taken. White-coat hypertension, or temporarily elevated blood pressure in a clinical setting, and misclassification based on the ability to measure blood pressure further complicate the use of blood pressure levels at a single time point as a measure of outcome quality. Standardizing a measure to indicate the quality of the process of hypertension management is also difficult since appropriate care is highly specific to the individual patient. Since treatment guidelines can vary based on a patient's age, comorbidities, and reaction to first- and second-line treatments, it may be difficult to judge a provider's process quality for hypertension management (Whelton et al. 2018). Patient adherence to treatment also plays a major role in determining the ultimate quality of hypertension management services, introducing additional components for potential measurement. While the current conceptualization of effective coverage is insufficient to capture all of the components related to need, use, and quality of hypertension management services, more flexible and comprehensive measurement frameworks exist.

Care cascades are tools which attempt to incorporate the quality of care into the measurement of service coverage, thereby measuring constructs similar to effective coverage. Care cascades generally start with the number of people in need of a service and include the successive steps of seeking care, receiving a service, receiving appropriate care (process quality), user adherence, and then the health gains achieved (Amouzou et al. 2019). These cascades are perhaps most recognizably used in global public health to monitor HIV/AIDS control, but they have also been developed for a range of maternal and child health interventions and services to manage other diseases such as tuberculosis, hepatitis C, and diabetes (Gardner et al. 2011; Amouzou et al.

2019; Ali et al. 2014; Safreed-Harmon et al. 2019; Alsdurf et al. 2016). Hypertension management also has a cascade of care with steps commonly described at the prevalence of high blood pressure, percent of hypertensives formally diagnosed, percent of hypertensives receiving treatment, and percent with controlled blood pressure (Figure 1.2). This hypertension care cascade framework has been used to describe hypertension control in populations in the United States since at least the 1980s and in India since at least 1990 (Cummings et al. 1982; National Heart Blood and Lung Institute 1985). In LMICs, the largest barriers to hypertension management are the diagnosis of individuals with high blood pressure, and the ability to achieve non-elevated blood pressure levels among individuals receiving treatment (Geldsetzer et al. 2019).

Figure 1.2: Standard hypertension care cascade across 44 low- and middle-income countries



Legend: Hypertensive population are undiagnosed individuals with mean systolic BP ≥ 140 mm Hg or a mean diastolic BP ≥ 90 mm Hg or currently taking blood pressure-lowering medication. Adapted from (Geldsetzer et al. 2019)

There is substantial overlap between the measurement of effective coverage and the use of care cascades (Table 1.3). Each step on a care cascade is necessary in order for effective coverage of services to be attained. Therefore, the major barriers (and interventions to remove these barriers) between steps on a care cascade will also inhibit (or improve) effective coverage of the same service. This concept is well reflected in Tanahashi's generic model of service coverage, as bottlenecks are identified along various stages on the pathway to coverage of effective services (Tanahashi 1978). However, the existing cascade framework for hypertension does not encompass enough of the factors related to the quality of care that result in effective hypertension management services. Namely, the existing care cascade does not account for the structure or process quality of hypertension management services, including capturing screening services, provider knowledge of quality treatment, ability to administer quality treatment, and patient adherence to treatment. Furthermore, hypertension management is influenced by several factors beyond the health system including individual, community/social, and environmental characteristics. By primarily focusing on outcome quality (the percent of previously diagnosed hypertensives with non-elevated blood pressure), existing effective coverage measures for hypertension and hypertension care cascades both place undue emphasis on factors that may be beyond the influence of the health system and suffer from the inability to identify where care is breaking down within a health system.

An expanded care cascade for hypertension management could contribute to an understanding of major barriers to achieving effective coverage of hypertension management services by highlighting gaps in the process of providing treatment at the population level. The care cascade contributes to filling the need for a global indicator for measuring effective coverage of

hypertension management services if it can be applied in low-resource settings. Additionally, if the gaps found to be most important within the care cascade can be incorporated into a single effective coverage metric, this could help to improve monitoring of health system performance, including progress towards UHC. Studies are therefore needed to develop and measure dimensions of an appropriate hypertension care cascade in LMIC contexts that have a burgeoning prevalence of hypertension. There is also a need to improve metrics for assessing effective coverage to account for characteristics of chronic diseases like hypertension. Such research would advance the current understanding of effective coverage of hypertension management services to achieve progress towards UHC. The concepts developed in this dissertation are applied to a real-world setting: the rural population of India's Bihar state.

Bihar, India

India is home to some 1.3 billion people, making it the world's second most populous nation. The country is comprised of 28 states and 8 union territories, between and within which exist huge disparities in income and health status. India's richest state, Goa has a per capita net state domestic product (equivalent of net domestic product, the gross domestic product minus depreciation on a country's capital goods) that is over 10 times greater than it's poorest state, Bihar (Ministry of Statistics and Programme Implementation 2020). In 2016, the average life expectancy at birth for an Indian born in Kerala was 11.3 years longer than that of an Indian born in Assam (76.4 in Kerala compared to 65.1 in Assam) (India State-Level Disease Burden Initiative Collaborators et al. 2017). All states in India are undergoing epidemiological transition, with a rising burden of non-communicable diseases and a decreasing proportion of infectious and maternal and child health associated diseases. In fact, from 1990 to 2016, the share of disability-adjusted life years (DALYs) lost due to non-communicable diseases increased from 30.5% to

55.4% across India (Indian Council of Medical Research, Public Health Foundation of India, and Institute for Health Metrics and Evaluation 2017). As chronic diseases gain prominence in Indian society, the Indian health system must adapt its the changing epidemiological profile in order to mitigate severe health and economic losses. Cardiovascular disease alone is estimated to cost the Indian economy US$2.25 trillion between 2012 and 2030 in direct health costs and lost labor (Bloom et al. 2013). Health is a state subject in India, meaning that state governments are responsible for both health services provision and the production of good health. Focusing this thesis on improving measurement of hypertension management services in a single state, Bihar, will provide relevant lessons for improving and organizing health services in Bihar and other Indian states because of the similar epidemiologic profile and growing burden of hypertensive-related diseases across India and LMICs globally.

Bihar is a state in northeast India with a population of about 100 million, making the state more populous than all but 14 countries in the world. The state covers a total area of about 95,000 square kilometers (about the same size as Portugal, or the American state of Indiana) and is geographically dominated by the Ganges River and its floodplains. Despite its immense population in a relatively small geographic area, 88.7% of the population is considered to live in rural areas (Office of the Registrar General & Census Commissioner 2011). Bihar is comprised of 38 districts and has an economy largely dependent on agriculture, with a population that often migrates to other Bihari districts, Indian states, and countries in the region to perform seasonal labor. As much as 5.6% of the population (6.7 million people) were residing out of the state in 2007, the vast majority of which were men seeking employment (N. Kumar and Bhagat 2012; Mistri 2015). The population is mostly young (19% are under the age of 6 and 58% are under the

age of 25) and Hinduism is the majority religion (83% of the population), although there is a large Muslim presence in the state (17% of the population translating to over 17.5 million people) (Office of the Registrar General & Census Commissioner 2011). Bihar is well known as a center of power, learning, and culture in India's history, and continues to produce influential national political leaders. However, in recent decades, Bihar has had some of the worst health outcomes among Indian states, and is plagued by high levels of corruption and poor governance.

The Bihari public health system is impaired by unequal access to healthcare, high inequity of services, insufficient institutional capacity and human resources, and deficient public health spending resulting in high out of pocket expenditure (Berman, Bhawalkar, and Jha 2017). The hierarchy of the public health services delivery system is supposed to entail one sub-health clinic per 3,000 population, one primary health center (PHC) per 20,000 population, one community health center (CHC) per 4 PHCs, one subdivision hospital per 500,000 people, and one district hospital per district (Berman, Bhawalkar, and Jha 2017). Although government records state that there are about 1,800 PHCs in Bihar, in reality, the majority of these lack infrastructure and/or staffing and are not functional (Berman, Bhawalkar, and Jha 2017). Even if all 1,800 PHCs in the state were functional, these would represent only 36% of the PHCs required to serve Bihar's population at government-prescribed per capita rates. There are 534 blocks in Bihar, of which 455 have PHCs that are open at all times and providing a full suite of services. To address constrained capacity in Bihar's public health sector, the Government of Bihar (GoB) receives technical support from the international NGO, CARE to improve population health and nutrition outcomes under the Bihar Technical Support Program (BTSP). With over $170 million in funding from the Bill and Melinda Gates Foundation (BMGF), the BTSP has been in place since

2011, and is a key program within Bihar's public health system. In addition to the public health sector, the private health sector plays an important role in providing services in Bihar.

As in many other states in India, Bihar has a pluralistic health system in which both allopathic and homeopathic systems of medicine are practiced. Most providers (86%) of either system of medicine practice in the private sector, which has been described as "dominant" in Bihar, comprising the source of care for the majority of the population seeking care (Mackintosh et al. 2016). In Bihar's allopathic system of medicine, qualified providers are those considered to be doctors who have received a Bachelor of Medicine and Bachelor of Surgery (MBBS), however there is a huge shortfall in the number of qualified providers in rural areas, as they mostly concentrate in urban centers. Alternative medical practitioners with degrees in Ayurveda, Yoga, Unani, Siddhi, and Homeopathy (AYUSH providers) play a large role in Bihar's private health marketplace and are also allowed to staff government-operated PHCs. In addition to these MBBS and AYUSH providers, there are a range of health care providers with no medical qualifications who often provide care in rural villages. These informal providers are often trusted members from the community in which they serve, charge nominal fees (generally 100 Rupees, or $1.37 USD per consultation), and are an important source of primary care services in rural Bihar. Informal providers come from a range of backgrounds including having some experience working at clinics in a non-clinician role, having limited health training such as community health worker training, or having no health-specific training or experience. A recent nationwide study showed that in Bihar, 3.9% of villages had access to a public MBBS provider, 7.6% had access to any MBBS provider (public or private), and 96.2% of villages had access to any provider, including AYUSH or informal providers (Das et al. 2020). The same study found that

the quality of care provided between states varied more than the differences in the quality of care provided within states, which tended to be highly correlated across provider qualifications. In other words, the knowledge of an informal provider in a richer state like Gujarat was substantially higher than the knowledge of a fully-trained MBBS provider in Bihar (Das et al. 2020). This means that people in rural Bihar are left with few options for receiving primary care from qualified providers, and that the quality of care they are receiving, regardless of their provider's qualifications, is among the worst in India. Against this backdrop, the rising burden of non-communicable disease in the state will further exacerbate the state's resources, placing additional burden on the health system.

Bihar is currently experiencing epidemiologic transition and is suffering from a double burden of acute and chronic conditions (42.6% of disease burden is due to communicable disease, 47.6% is due to noncommunicable disease) (Indian Council of Medical Research, Public Health Foundation of India, and Institute for Health Metrics and Evaluation 2017). Despite the fact that about 70% of the public state health budget is allocated for primary care, little has been done to quantify the state's ability to effectively deliver services to manage chronic conditions at the primary care level (Berman, Bhawalkar, and Jha 2017). Further, the private sector is currently providing the majority of hypertension management services, as three times as many people avail such services from private providers than from government facilities in India (Biswas, Singh, and Singh 2016). Reasons for private sector preference in India in general include perceived poor quality of care in PHCs, a lack of available drugs and/or tests, long waiting times, and far travel distances to public options, however the reasons for private sector preference specific to hypertension care are not well known (Sengupta and Nundy 2005). One study found that quality

of care is an important determinant of facility choice among households with hypertension (Kujawski et al. 2018). This finding suggests that the perceived low quality of PHCs could be the factor driving individual preference for private sector providers for hypertension management in India. There is an urgent need to understand gaps in providing hypertension management services, as Bihar (and other LMICs) cannot afford to ignore the impact of chronic diseases such as hypertension.

Measuring effective coverage of hypertension management services in rural Bihar

Appropriate consideration of contextual factors is essential for ensuring internal and external validity of studies. There are several contextual factors in Bihar that may influence the measurement of effective coverage for hypertension management services and should be considered. Previous studies have considered contextual factors that influence evaluations in two main categories: impact-related factors, such as baseline levels and patterns of hypertension in the population that may influence changes in indicators, and implementation-related factors, such as the characteristics of existing health systems and programming (Victora et al. 2005). This section presents an overview of these impact and implementation-related contextual factors.

Quantifying the burden of hypertension in Bihar is key to understanding the need for hypertension management services in the state. The best estimates of state-wide hypertension burden come from the National Family Health Survey (NFHS), conducted about every five years. Only the two most recent rounds of the NFHS, conducted in 2015-2016 (NFHS-4) and again in 2019-2020 (NFHS-5), contain estimates of hypertension burden. During these surveys, trained enumerators measured systolic and diastolic blood pressure of respondents three times

(using a portable Omron blood pressure monitor, model HEM-8712) with five minutes of sitting before the first measurement and at least five minutes between each measurement (Prenissl et al. 2019). Individuals were classified as hypertensive if mean systolic blood pressure was ≥ 140 mm Hg or mean diastolic blood pressure was ≥ 90 mm Hg or if respondents answered yes to either being told by a health worker at least two times that they had high blood pressure or that they were currently taking a prescribed medicine to lower blood pressure. Results from the NFHS demonstrate that the prevalence of hypertension among those 15 – 49 years old has steadily increased for both men and women in rural Bihar (Table 1.4). Several statewide and national studies have reported hypertension prevalence based on the results of the NFHS surveys (Prenissl et al. 2019; S. Ghosh and Kumar 2019). Other studies have attempted to quantify the burden of hypertension at a sub-state level.

Table 1.4: Change in hypertension prevalence in Bihar among those age 15-49 over time

	NFHS 4 (2015-2016)			**NFHS 5 (2019-2020)**			**Percent Increase**		
	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
Men	13.5%	10.5%	12.3%	10.4%	11.1%	12.3%	*-23%*	*6%*	*0%*
Women	7.8%	8.3%	8.2%	9.1%	8.8%	8.9%	*17%*	*6%*	*9%*

Legend: Hypertension prevalence is defined as having a mean systolic BP ≥ 140 mm Hg or a mean diastolic BP ≥ 90 mm Hg or currently taking blood pressure-lowering medication

Literature searches in SCOPUS, PubMed, and Google Scholar have returned limited studies that quantify the prevalence of hypertension in Bihar. The oldest studies on hypertension in Bihar come from 2010. One 2010 study found the prevalence of hypertension in a rural block of the Patna district to be 23.7% among adults aged 30 and older (Singh et al. 2011). Also in 2010, researchers found that the prevalence of hypertension was relatively low (11.4%) among adults over age 20 in a majority Muslim block in rural Bihar (A. Ghosh et al. 2013). Since then, studies have assessed hypertension prevalence in specific sub-populations. A 2015 study found a high

prevalence of pre-hypertension (10.9%) and hypertension (4.6%) among school-going adolescents in Patna (P. Kumar et al. 2017). Among the elderly, a 2017 community-based study in rural Katihar district found that 47.7% of individuals over the age of 80 had hypertension (Al Adil 2018). These studies suggest that the prevalence of hypertension may fluctuate geographically across Bihar. The scarcity of available information suggests that more research is needed to assess and improve hypertension management in the state.

Several contextual factors influence the impact of interventions to improve hypertension management services. In Bihar, there is a high prevalence of factors that contribute to increased risk of raised blood pressure in individuals. The most ubiquitous risk factor is the high level of air pollution in the state. Both short- and long-term exposure to air pollutants are significantly associated with higher incident hypertension (Giorgini et al. 2015; Prabhakaran et al. 2020). Residents of Bihar have the third highest exposure to air pollution across Indian states, and have exposure to some of the highest levels of ambient particular matter and household air pollution in the region (Balakrishnan et al. 2019). Causes of poor air quality in the state include crop residue burning, widespread use of solid cooking fuels in households, and construction and other, often unregulated, industry. At the individual level, risk factors for hypertension include alcohol and tobacco use (Ezzati et al. 2015). Measuring alcohol use in Bihar is complicated since it is a "dry" state which has implemented an alcohol-prohibition policy. Over half (53.5%) of all adults use tobacco, and only 15.0% of users had been advised to quit by a health care provider (World Health Organization 2011). Although we found no published research on the subject, the minimal receipt of tobacco cessation advice could be representative of low levels of public (and provider) knowledge towards hypertension risk factors. These individual and environmental risk

factors for high blood pressure are influenced by dynamics which exist beyond Bihar's health system and complicate the measurement of non-elevated blood pressure as an indicator of health system performance. In addition to risk factors and patterns of hypertension burden, Bihar's pluralistic health system provides implementation-related contextual factors that influence evaluations of hypertension management services.

As previously discussed, the reliance on private, and often unqualified, providers in Bihar complicates efforts to assess health system performance for provision of hypertension management services. AYUSH systems of medicine are often preferred to allopathic treatment and multiple studies in Bihar have attempted to demonstrate the health benefits of AYUSH treatment for chronic diseases (Rudra et al. 2017; Sharma et al. 2019). The prevalence of multiple systems of medicine obfuscates the assessment of quality of processes to treat hypertension since the content of care is likely different across these systems. Further, patient preference for informal providers for chronic care presents methodological issues when researching the quality of care people receive (Raza et al. 2016). Informal providers, who are often demonized by the public sector and physician associations, can be hesitant or unwilling to participate in research efforts, as they are generally suspicious of government motivations. These informal providers can provide essential health services but if they are neglected by government and other formal actors, as in the case of COVID-19 response, the entire community may suffer (Rao et al. 2021). Although there have been some efforts to integrate informal providers into the public health system, there are serious gaps in the state's comprehensive response to the rising burden of hypertension.

The Government of Bihar is not currently prioritizing chronic disease management. While India's central government has initiated a National Programme for Prevention and Control of Cancers, Diabetes, Cardiovascular Diseases and Stroke (NPCDCS) as the primary intervention for NCD control, the program requires adequate financing at the state level. Bihar spends $7 per capita on NCD prevention and control, the second lowest among Indian states and only one fifth of the national average spending (I. Gupta and Ranjan 2019). The combination of weak government programming to provide NCD management services, strong presence of homeopathic and informally trained providers, and the high rate of hypertension risk factors combine to make Bihar a challenging study area for researching hypertension management services.

Thesis Aims

This thesis will inform health systems performance measurement in the context of chronic disease management through the following aims:

Aim 1: Develop a measurement framework for tracking effective coverage of hypertension management services in resource-limited settings. A scoping review of published literature will synthesize how effective coverage (and related concepts) of hypertension management has been historically defined and measured in low- and middle-income countries. Findings will be operationalized into a framework for measuring aspects of effective coverage relevant to hypertension management services in low- and middle-income countries.

Aim 2: Measure and describe key dimensions of effective coverage of services to manage hypertension in rural Bihar, India. Applying the framework proposed in aim 1, steps along the expanded cascade of care will be measured to describe the supply- and demand-side features of hypertension management, identify barriers to effective hypertension management, and propose strategies for improving hypertension management in rural Bihar, India.

Aim 3: Assess the level of effective coverage of hypertension management services in rural Bihar, India. Findings from aims 1 and 2 will inform the construction of an index measure of effective coverage of hypertension management services. The coverage of key services will be measured and aspects of structural and process quality of primary care providers will be combined into an overall quality index. The two components (coverage and quality) will be combined to determine the effective coverage of hypertension management services in rural Bihar and will inform the global monitoring of effective coverage of hypertension-related services in the context achieving UHC.

Conceptual Framework

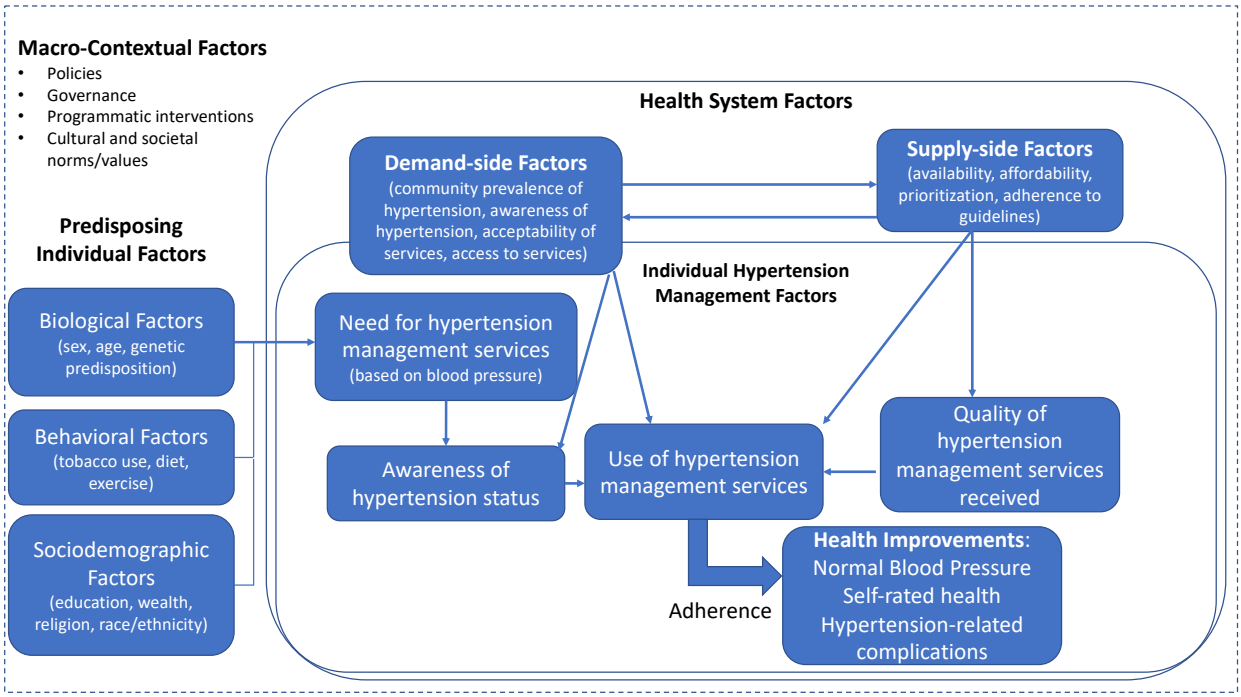
The following conceptual framework has been developed to describe how expanding effective coverage of hypertension management services leads to health improvements. The goal of this framework is to describe the factors (especially the health system-related factors) that contribute to improvements in health among those with hypertension. The framework adopts a patient-centric approach and incorporates factors at several different levels. Influential works that informed the framework's development include Shengelia's effective coverage definition, Tanahashi's model for bottleneck analysis, Andersen's behavioral model of health services use,

Donabedian's categorization of quality, the chronic care model, and the CDC's policy framework for cardiovascular risk (Shengelia et al. 2005; Tanahashi 1978; R. M. Andersen 1995; Donabedian 1988; Homer et al. 2008). The original description of effective coverage is essential to understanding how the use of quality services translates to health improvements among those who are in need. Andersen's behavioral model informs the interconnected roles of environments, population characteristics, and individual health behaviors with outcomes, and further links various types of access to health outcomes. Tanahashi's framework is useful for identifying bottlenecks along the pathway from access to services to health gains for patients. The chronic care model applies many of the concepts previously described in general terms of providing health services to treat long-term diseases. Importantly, this model recognizes the relationship between health systems, specifically service providers, individuals, and communities and their importance in managing chronic diseases. Donabedian's framework for quality helps describe the features that contribute to service quality, namely structures, processes, and outcomes. Finally, the CDC policy framework helps to further frame these factors in terms of improving cardiovascular health. Additionally, country-specific conceptual frameworks developed for controlling hypertension were considered to ensure that the framework under development was flexible enough to incorporate key aspects in various contexts (Huang et al. 2016; Chimberengwa and Naidoo 2019; Chukwuma et al. 2019).

The final conceptual framework acts as a flowchart of factors that interact at multiple levels to contribute to or inhibit health benefits among those in need of hypertension management services (Figure 1.3). It starts with individual- and macro-level contextual factors that influence an individual's predisposition to needing hypertension management services. The individual risk

factors for hypertension have been previously described and include biological factors (such as sex, age, genetic predisposition to hypertension, and factors during growth and development), behavioral factors (such as diet, level of physical activity, smoking and tobacco use, alcohol use, and level of stress), and individual socio-demographic factors (such as wealth, education, religion, and other racial or ethnic factors). Additionally, macro-contextual factors, such as policies (e.g. sodium-reduction policies), governance (e.g. ability to provide public goods like clean air), programmatic interventions (e.g. intensity of chronic disease programming), and other cultural and societal norms and values may contribute to an individual being more or less likely to have a need for hypertension management services. These macro-contextual factors also influence the health system and individual management of hypertension.

Figure 1.3: Conceptual framework for health improvements from effective hypertension management



After describing the factors that place individuals at high risk for hypertension, the framework incorporates factors related to an individual's hypertension management, starting with the individual's need for services. The services required by an individual may vary based on their risk of hypertension and their current blood pressure level. For example, normotensive individuals are generally in need of interventions to educate and raise awareness, and require regular blood pressure measurement, whereas hypertensive individuals require behavioral changes and pharmacotherapy. The need for services can be based on several different typologies, but this framework adopts a normative need for services (based on International Society of Hypertension Guidelines), as it is the most comparable across contexts (Unger et al. 2020). Next, an individual must be aware of their hypertension status in order to purposively utilize any services which may lead to an improvement in health. These services may include educating patients, providing lifestyle advice, or writing prescriptions and making follow up appointments. These services generally constitute the "process" component of Donabedian's conceptualization of quality of care, which also influence the extent to which health improvements are realized. Adherence to the services (in terms of both patient compliance/adherence and continued provider follow-up) is a necessary condition to achieving sustained health gains over time. These health gains represent the "outcome" component of Donabedian's quality framework and can either be narrowly defined (e.g. normal blood pressure levels) or represent broader conceptualizations of health (e.g. self-rated health).

An individual's hypertension management is occurring within the larger health system. Both demand- and supply-side factors influence the health system's performance and the individual's ability to manage hypertension. On the demand side, the community's need for hypertension

management services (as determined by levels of hypertension awareness and prevalence) may influence the kinds of services available at the primary care level. Additionally, the kinds of services that are acceptable, and accessible to the community may influence the choices an individual makes in terms of managing their blood pressure. Examples include whether an individual is more likely to be aware of their hypertension status (e.g. if community awareness is high, an individual may be likely to request blood pressure screening services) and also how they choose to receive services (e.g. from a pharmacist or from a formally trained doctor). These demand-side factors are influenced by and also influence the supply of services that are available in many LMIC markets. Public and private health systems have variable levels of "structural" quality, including levels of staffing, medicines and supplies, and levels of training. These supply-side factors primarily influence the provision of health services by dictating the service delivery platform (e.g. in-home visits from community health workers) and the overall quality of services received.

Previous research has described the individual biological, behavioral, and sociodemographic factors associated with hypertension prevalence and control (James et al. 2014). There is some evidence about the systemic policy options that reduce the prevalence of hypertension and improve control in high-income settings, but there is far less research on hypertension management in LMICs (Institute of Medicine (US) 2010). While several studies have examined the specific individual factors associated with hypertension prevalence, treatment and control in specific countries, there is little work that comprehensively assesses health system performance in hypertension management and control in LMICs. Some studies have examined drivers of patient decision-making and have combined this information with aspects of service quality, but

these studies are limited in scope and do not provide much insight about the quality of hypertension management services provided by the health system (Kujawski et al. 2018; Gabert et al. 2017; Wollum et al. 2018; Galson et al. 2017). There is a need to further describe the interactions between the quality of hypertension management services, the use of these services, and the impact on community health to inform the organization of future-facing health systems that optimize population health outcomes. This thesis generates insights to fill this information gap in our understanding of health systems and hypertension management in LMICs.

The Assessment of Primary Health Care in Bihar Study

The thesis leverages the data collection activities from a larger study to assess the primary health care delivery systems in rural Bihar, India. Whereas comprehensive primary health care systems include a wide scope of activities, including interventions delivered by community health workers and primary prevention services, this study focuses on the facility-based service delivery component of primary care. The parent study was designed specifically to understand reasons for the low utilization of PHCs for curative and chronic care services in rural Bihar. Previous studies have pointed to factors including distance to provider, low structural and clinical quality of care, the costs of seeking care, and the functionality of outreach services as important determinants of patient care seeking (Rao and Sheffel 2018). However, little is known about the quality of care provided by public and private (both qualified and unqualified) providers in rural Bihar, or the types of primary care providers patients seek out first. The parent study had the following objectives:

1) To identify the type of primary care providers first contacted by patients (i.e. women, adult men, children, and the elderly) seeking ambulatory care in rural Bihar.
2) To estimate the level of structural and clinical (i.e. process) quality of care among public and private (formal and informal providers of allopathic care) primary care providers in rural Bihar.
3) To understand the drivers of patient choice of primary care provider (e.g. structural and clinical quality of care, distance, cost). In particular, how these factors determine patient decisions to use – or bypass – public sector primary care facilities.

To achieve these objectives, a series of cross-sectional surveys was conducted to collect information from a sample of households as well as public and private primary care providers. The Assessment of Primary Health Care in Bihar Study is a component of the research arm of the BTSP, through which Oxford Policy Management (OPM) is funded by the Gates Foundation. Johns Hopkins University was subcontracted by OPM to design the study, OPM implemented the data collection with in-country staff, and CARE India was a key stakeholder in the project as the primary provider of technical support to the Government of Bihar. The following describes the design and methodology for the two phases of data collection which consisted of a household survey, and provider assessments.

Phase I: Household Survey

Study Design

The first phase of data collection is a multi-stage cluster sampling household survey designed to provide state-representative estimates of individual care-seeking behaviors in rural Bihar. The

multi-stage cluster sample methodology has the advantage of increased feasibility, but yields a larger variance than a simple random sample, and is utilized by many surveys in developing countries including the Demographic and Health Surveys (DHS) and Multiple Indicator Cluster Survey (MICS) (International Institute for Population Sciences (IIPS) and ICF 2017; UNICEF n.d.). Sample size calculations for the household survey were motivated to detect differences in care-seeking patterns based on the quality of PHC providers. One study from another state reported that use of the local PHC improved with better quality clinical care, but only up to a point (Rao and Sheffel 2018). In this study, the quality of clinical care was conceptualized as provider competency, which was determined through the use of clinical vignettes to assess provider ability to treat a range of health conditions. The study found that an averagely equipped PHC with the least competent provider (competency score of 15 out of 100) who is regularly present is expected to be visited by 8% of local individuals that are sick and seek care outside home. The study also reported that if the same PHC had an averagely competent provider (competence score of 47 out of 100) it would be visited by 46% of local patients. Based on this study, we assume that averagely equipped PHCs in Bihar with an averagely competent clinician (i.e. score of 50 out of 100) receive 50% of the visits by local residents who are sick. Thus, to detect a 10% difference in the proportion of local patient visiting PHCs with and without competent clinicians with 80% power and α=0.05, a total sample of 776 individuals who are sick and seek care is required (Annex 1). Estimates from the 2014 National Sample Survey (NSS) indicate that 6% of the population of rural Bihar was sick in the two weeks prior to the survey and 66% of those sick individuals sought treatment outside home (Ministry of Statistics and Programme Implementation 2014). Adjusting for a design effect of 2 (based on NFHS 4) and accounting for care seeking patterns, the required sample size is 2,352 sick individuals who

sought care (International Institute for Population Sciences (IIPS) and ICF 2017). Considering estimates of illness episodes prior to the survey, in order to include 2,352 patients who sought care outside the home, we require a sample of approximately 39,192 individuals. Assuming an average household size of 5, and accounting for a 20% non-response rate, the survey needed to sample at least 9,797 households. From sample size calculations for the provider assessments, we required 70 PHCs. Within the 70 PHC catchment areas, we selected 5 villages per PHC and 30 households per village to arrive at a target sample size of 52,500 individuals and 10,500 households for the survey.

The primary sampling unit for the household survey was public primary health centers. Out of the 455 fully functional PHCs in Bihar (defined as all PHCs providing 24/7 child delivery services), 70 PHCs were randomly selected using stratified random sampling proportional to number of PHCs in Bihar's nine divisions. The sampling frame was a census of all PHCs, provided by CARE India. The secondary sampling unit was villages within the primary health center's catchment area. From the 2011 Census, each PHC has a complete list of all villages that fall within its catchment area (the geographic area that PHC is designed to serve). The average PHC catchment area contains 12 villages, and from the census of all villages in the catchment area, 5 villages were systematically randomly sampled by probability proportional to size. Size represents the estimated population within the total catchment area of each PHC as estimated by the National Census (2011). A total of 350 villages were selected for data collection. A listing of all households within each sampled village was carried out by the Public Health Foundation of India (PHFI) between September and December, 2019. The listing team ascertained the name of the household head, the religion and caste of the household, and the number of members in the

household for entire villages or for a randomly selected segment of a village if there were more than 350 households in a village. In this manner, we determined that the average sampled village had about 1,200 households and a population of approximately 6,500 people. From each village listing of households, 30 households were randomly selected for inclusion in the study, for a target sample of 10,500 households. Every member of a selected household was included for interview in the survey, although different modules were applicable for different subgroups (e.g. only adults over the age of 30 were asked specific questions about chronic diseases, mothers were asked questions about the health of children under the age of 18).

Study Tool

The tool used to collect data in the household survey was a structured questionnaire with five sections. The first section collected information on the location of the household, demographic information about all household members including sex, age, marital status, and highest completed schooling. The second section was related to care-seeking during illness, in which each household member was asked about their primary occupation, monthly income, self-rated health, and whether they had experienced a health problem in the last 30 days. Individuals who responded that they had experienced a health problem were asked about the health problem, how long they have had it, how serious the condition was, whether they sought care outside the home to treat the condition, and reasons for seeking care (or not seeking care) from that particular provider. Information about the provider was also collected, including the type of provider (e.g. medical shop, private clinic, or PHC), the name of the provider, the provider's location, reasons for choosing the particular provider, time and distance to reach the provider, trust and satisfaction with the provider, and cost of treatment. Further questions were asked about how the

illness affected the individual's ability to work, and whether the individual was hospitalized in the last year. This section was asked to each adult (over the age of 18) in the household when possible, with the next closest family member (generally the female head of household) answering for adults who were not present or for children. The third section asked questions about five common chronic conditions (hypertension, diabetes, heart disease, asthma, and lung disease) to all adults over the age of 30. This section asked whether individuals had ever been diagnosed with one of these chronic diseases by a health worker, whether they were currently receiving treatment, and about characteristics of their usual source of care to manage the chronic condition (structured similarly to the care-seeking module in section 2). The fourth section asked women aged 15-49 years old about if they had ever given birth and whether they had given birth in the last year. If so, the mother was asked questions from a module about the child's health (including issues related to child diarrhea and immunization) and care-seeking during pregnancy (structured similarly to the module in section 2). The fifth and final section collected information from the head of the household about the local PHC (including whether anyone has visited the PHC in the past year, travel distance to PHC, interactions with community health workers, and participation in community groups), and about the household's socioeconomic status (including religion, caste, main household occupation, household assets, and total household expenditure).

The household survey tool was developed by a team of researchers from Johns Hopkins with inputs from team members from OPM and CARE India. Wherever possible, the tool used validated questions from established household surveys implemented in the same context to ensure comparability (especially the NFHS and NSS). The survey tool was translated to Hindi by local researchers and pilot tested in Bihari communities that were not included in the household

survey sample. Two rounds of pilot testing (in August and September 2019) were conducted, during which cognitive probing was conducted with community members to ensure that questions were easy to understand and were addressing the intended constructs (Bowden et al. 2002; G. B. Willis 1999). Questions were then revised as necessary and the final tool was entered into computer-assisted personal interviewing (CAPI) software. A manual was also developed by the study team to assist in the implementation of the tool based on experiences and lessons learned during pilot testing and development. Specific questions from the household survey that are relevant to this thesis are included in Table 1.5.

Table 1.5: Key questions from household survey tool

Concept	Question in Household Survey	Response Options	Reference Survey
Need	Have you ever had your blood pressure measured by a doctor or other health worker?	Yes No Don't Know	Same wording as NFHS 4
	Have you ever been told by a doctor or other health worker that you currently have hypertension or high blood pressure?	Yes No	Same wording as NFHS 4
Use	How long ago were you first diagnosed with hypertension?	(enumerator enters integer)	N/A
	Have you been taking any medications or other treatment for hypertension during the last 12 months?	Yes No Don't Know	Same wording as NFHS 4
	In the past 12 months, have you sought care from any provider outside your home to manage your hypertension?	Yes No Don't Know	Same wording as NSS
	How many visits to a doctor or health worker have you had in the last year to manage your hypertension?	(Enumerator enters integer)	N/A
	From which type of provider do you usually receive care to manage your hypertension?	ASHA ANM Village Health Sanitation and Nutrition Day Government clinic Government hospital Private doctor/clinic Private Hospital Traditional Healer Pharmacy/Compounder	N/A
	On average, every month, how much do you spend on managing your hypertension? Please consider medicines, doctor consultation, diagnostic tests, and other costs.	(Enumerator enters integer)	
Quality (outcome)	In general, how would you rate your health today?	Excellent Good Fair Poor Very Poor	
	Have you ever been hospitalized because of your hypertension?	Yes No Don't Know	N/A
	Overall, how satisfied are you with your experience with this provider?	Very satisfied Somewhat satisfied Somewhat dissatisfied Very dissatisfied Don't know	N/A

Data Collection

Fieldwork and data collection for the household survey was led by OPM. A team of 35 local enumerators with previous experience conducting household surveys and at least a graduate degree in the social sciences was hired to conduct the fieldwork. Teams were trained over the course of seven days on the purpose of the study and how to correctly use the survey tool on electronic tablets using the CAPI software. The training also involved three days of field practice with the tool before the start of data collection. Written or oral consent to participate in the survey was obtained from the head of each household and participants were informed that they could stop answering questions at any time. One supervisor was assigned to each field team of seven enumerators. The supervisor observed surveys and conducted spot checks on the collected data to validate answers to key questions with 20% of the households. Central supervisors overseeing the entire data collection process also visited field sites with teams to provide oversight twice weekly. Daily debriefing sessions were conducted across the field survey teams and errors or difficulties were reported to the central supervisors. Twice a week, all of the supervisors had a call with the Johns Hopkins team to discuss any issues. At the end of each day, data was automatically uploaded to a central server from all of the tablets. This data was automatically run through a logic-checking do-file in Stata, and any outliers, unusual data, or missing data were flagged and checked with supervisors and enumerators to ensure accuracy of collected data (StataCorp 2014). The study also required collection of GPS data to inform the second phase of data collection.

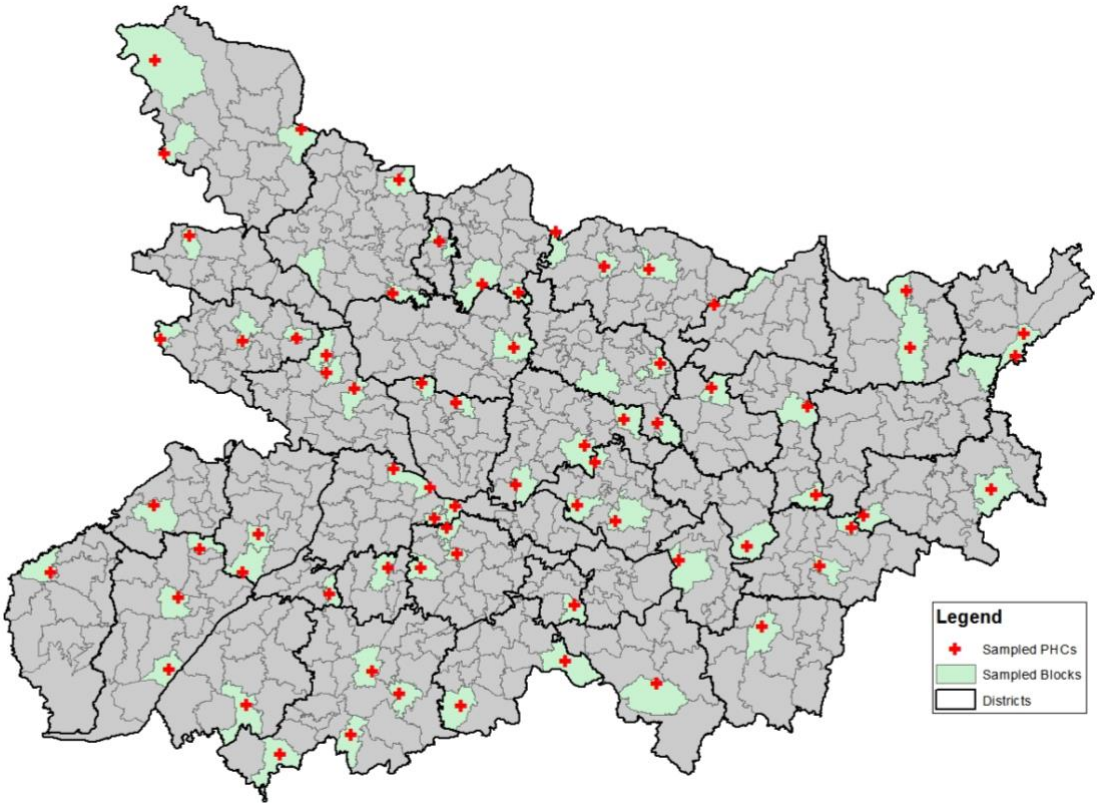
The names and locations of all public facilities and private providers/facilities where household members sought care in the past month, or where care was usually received for chronic disease

management, were recorded. Following the household survey, a second team used the location information provided in this list to locate providers in the sampled villages from whom respondents reported receiving care. The team recorded the GPS location and contact information of every sampled PHC and all private providers (formal and informally trained) mentioned in the household survey that were reported to be within 15 minutes driving distance or 5 km of the respondent's household. This list of providers constituted the sampling frame for the second phase of provider assessments.

Fieldwork for the household survey was scheduled to begin in September 2019, however monsoons and severe flooding in Patna forced the team to reschedule. Ultimately, fieldwork for the household survey took place from November 2019 to March 2020. Due to the spread of COVID-19 in India, data collection was stopped on March 13, 2020. At this point, the first round of the household survey was completed, however the scheduled follow-up visits were not conducted, thus efforts to minimize bias from non-response due to migration or unavailability were not implemented. The household survey yielded a sample of 39,486 individuals from 8,365 households from 343 villages across 70 blocks in 37 districts (Figure 1.4). Major reasons for non-response included the fact that households had migrated seasonally (n= 1,007 households), households were scheduled for re-visits but the follow-up visits were not completed due to the COVID-19 outbreak (n=660 households), and refusal among Muslim households due to suspicions over the Citizenship Amendment Act and the National Register of Citizens (n=404 households). Since we were not able to do follow-up surveys, the sample from our household survey may have some systematic bias because it excludes migrant populations and Muslim households. The final sample covered 80.2% of the envisioned sample of households in rural

Bihar (the non-response rate was 19.8%) and contained slightly more than our required sample size of 39,192 individuals.

Figure 1.4: Map of sampled primary health centers and blocks in Bihar, India



Data Analysis

Information collected from the household survey in CAPI was exported into a Stata dataset by the OPM team. The Johns Hopkins team created an automated analysis to check for outliers, missing values, and unusual estimates and these observations were discussed with the data collection team, and the datasets were cleaned accordingly. The multi-strata survey design has implications for the calculation of state-wide estimates for population health indicators. Sample

weights to account for the survey design and non-response are applied to all descriptive statistic calculations to obtain state-wide representative estimates for rural Bihar.

Phase II: Provider Assessments

Study Design

The second phase of data collection relied on provider-based data collection techniques to assess clinical quality of care. Clinical quality of care is an elusive concept to measure and methods employed to assess different domains of quality (i.e. structure, process, and outcomes) deserve additional attention. Measuring structural quality is primarily done at the facility level, through the use of health facility assessments. There are a number of data collection methods that can be used depending on the purpose of the study, but these tools generally seek to quantify the availability and quantity of inputs (e.g. human capital, infrastructure, and supplies of drugs and equipment) which impact health service delivery (Edward et al. 2009; Nickerson et al. 2015). While they provide important information about available infrastructure, a common critique of these facility-based assessments is that they are poorly correlated with the actual provision of quality care and do not capture key elements of process quality (Macarayan et al. 2018; Hannah H Leslie, Sun, and Kruk 2017).

Four methods are primarily used to measure quality of care related to processes in health systems research: chart reviews, standardized patients, clinical vignettes, and direct observations of provider-patient interactions. Chart reviews can be used to assess performance on clinical effectiveness measures, and are regularly used in high income countries to retrospectively assess performance of clinical management (Vassar and Matthew 2013; vonKoss Krowchuk, Moore,

and Richardson 1995). Due to a lack of systematic record keeping in many LMIC contexts, including Bihar, this methodology is infeasible. The use of standardized patients entails training actors to seek care while presenting with a pre-determined set of clinical symptoms and documenting what advice clinicians provide in response (Kwan et al. 2019; King et al. 2019; Wiseman et al. 2019). These studies have been used extensively in India and other LMICs to assess healthcare providers' knowledge and practice in diagnosing and treating a number of common diseases (Das et al. 2012, 2015; Miller, Das, and Pai 2018; Das and Gertler 2007; Das and Hammer 2007; Das et al. 2016). Since standardized patients require patient-actors to have some clinical training, this is a resource-intensive method. Clinical vignettes are similar to standardized patients because providers are presented with a standardized case, but in this method, one interviewer poses as a hypothetical patient (and answers the provider's questions) and the other interviewer records the processes that the provider performs in order to diagnose and treat the case. A substantial body of evidence has demonstrated that provider knowledge, as assessed by clinical vignettes, is a valid measure of the process of care provided in actual clinical practice (Peabody et al. 2000; Dresselhaus et al. 2000; Peabody, Luck, et al. 2004; Peabody, Tozija, et al. 2004; Dresselhaus et al. 2004; Peabody and Liu 2007). Unlike standardized patients, since providers are aware they are being evaluated, the Hawthorne effect may influence provider performance in clinical vignettes. [2] As such, vignettes can be interpreted as an upper bound on the quality of care of which a provider is capable (Das and Hammer 2014). A final method for assessing the process quality of care is by directly observing patient-provider interactions. These so-called patient observations, or direct observations, have the benefit of

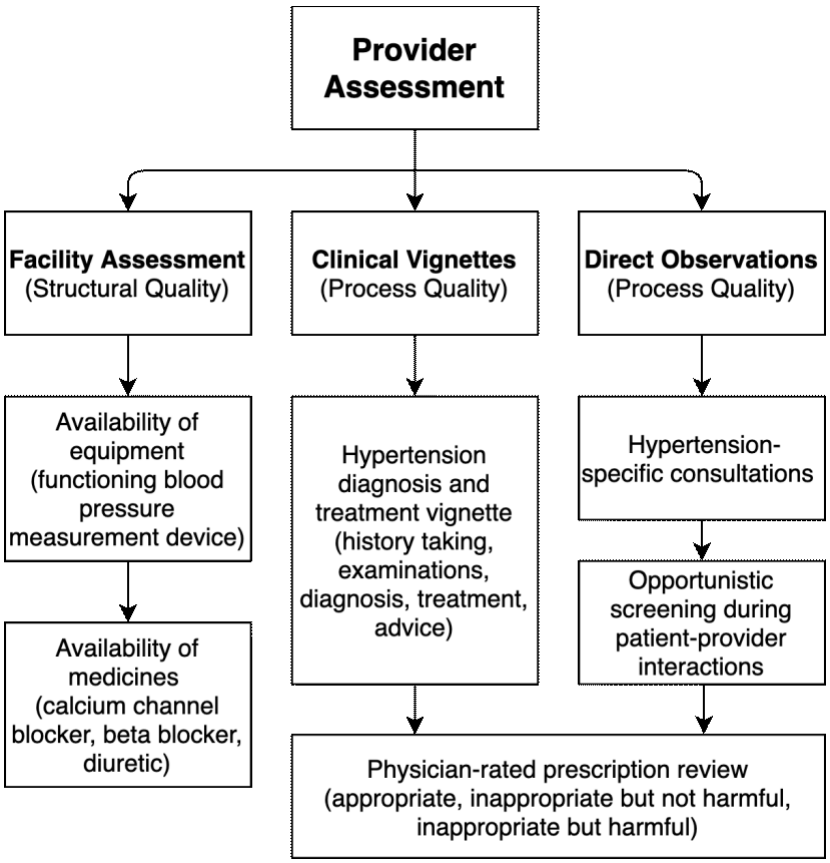
[2] This effect was originally documented by (Mayo 1933), and is well-described by (Benson 2000). The methodology of the original experiment and the description of the Hawthorne effect have since been debated (Jones 1992; Wickström and Bendix 2000), but the original understanding of this effect is still widely recognized today.

observing what providers actually do during a consultation (Aujla et al. 2020). Several researchers have documented a difference between what providers say they will do for patients (in clinical vignettes) and what they actually do (in direct observations), coining the phrase the "know-do gap" to demonstrate this principle (Leonard and Masatu 2005; Mohanan et al. 2015; Leonard and Masatu 2010). However, the quality of data collected through direct observations is also impacted by the Hawthorne effect, and is extremely time-intensive, as it requires a large number of observations to achieve reasonable sample sizes for specific, less common diseases. Linkages between the process of health services provision and health outcomes are essential to understanding how the quality of care can result in improved health (Mant 2001).

While process measures are direct measurements of the quality of care provided, outcome indicators reflect all aspects of care and are generally of greater intrinsic interest because they directly represent improvements in health. Outcome measures can be assessed by reviewing hospital records, however these records are generally not available in LMICs. Instead, population-level outcomes are generally measured through household surveys that are representative of a broader population. Phase I of the Assessment of Primary Health Care System in Bihar study collected several indicators of outcome quality related to hypertension management, including self-rated health, hospitalization outcomes, and patient satisfaction (Table 1.5). The provider assessment employed several of the aforementioned methodologies to determine the structural and process-related quality of care among primary care providers in rural Bihar.

Three data collection activities were implemented to understand the quality of services provided in the public and private primary health care system, namely (i) a facility-based assessment to measure structural quality of facilities/practices; (ii) clinical vignettes with the primary (or available) provider at a health facility/practice to measure provider knowledge (process quality); and (iii) direct observations of new[3] provider-patient consultations to measure provider practice (process quality). Taken together, these tools were designed to provide a comprehensive understanding of the structural- and process-related quality of care among public and private (both formal and informal) primary care providers in Bihar. The tools also provide a detailed overview of several aspects of quality of care related to hypertension management (Figure 1.5).

Figure 1.5: Provider assessment tools related to hypertension quality of care



[3] Only new provider-patient consultations were considered in order to standardize the history-taking and investigations portions of the direction observation

The sample size calculation for the provider assessment was motivated to detect a difference in the quality of care between public and private primary health care providers. The unit of analysis is a health care facility, and the main provider (or medical officer in charge, if there are multiple clinicians on duty) answered the tool. For public providers, this included PHC clinicians, and private providers included formal and informal providers practicing allopathic and AYUSH systems of medicine. One study from another Indian state estimated that clinicians at PHCs had a mean knowledge score of 57 on a scale ranging from 0-100 (Rao and Sheffel 2018). The sample size calculation suggests that to detect a 5-point difference in score between public and private providers with 80% power and α=0.05, a sample of 34 clinicians in each group (total of 68 clinicians) is required (Annex 1). Adjusting for a 20% non-response rate and DEFT of 1.5, and assuming that one clinician would be sampled from each facility, the total number of facilities required was 132, or 66 public facilities and 66 private facilities. A previous study found that the average Indian village has 3.2 primary healthcare providers, the majority of which operate in the private sector (Das et al. 2020). Our sample therefore needed to include providers from at least 66 PHCs and private providers from at least 20 villages to detect a 5-point difference in quality score between public and private clinicians. We rounded this upwards to include 70 PHCs and private providers from 70 villages in our study. Our study's sample represented about 15% (70/455) of the functional block level PHCs in Bihar.

All three provider assessment activities were carried out at each of the 70 PHCs sampled in Phase I. One of the five villages from each PHC catchment area was selected through simple random sample and all three provider assessment data collection activities were conducted with all providers/facilities utilized by respondents and identified in Phase I that were within close

proximity (5 kilometers) of that village. This included all public, private, and informal providers from which care was sought. Even though they are an important source of care, medical shops and pharmacies were excluded from the Phase II data collection activities because pharmacists/chemists were unable to answer most of the modules of the provider assessment during pilot tests. The final sample size was estimated to be 70 PHCs and 224 private providers for the facility assessment and clinical vignettes. For the patient observation tool, it was envisioned that 5 patient interactions would be observed per facility, for a total sample size of 350 patient observations at public clinics and 1,120 patient observations at private facilities.

Study Tools

Development of the three study tools for the provider assessment followed a similar pattern. First, a review of similar tools (ideally previously validated in India) was conducted to ensure that question items had been tested and could be comparable over time. Next, the Johns Hopkins team developed the tool, with inputs from clinicians, colleagues at OPM, and partners at CARE India. Third, the tool was translated into the local language and entered into a CAPI software. Finally, the tool was pilot tested and adjusted based on experiences and lessons learned during pilot testing. The tools were pilot tested in January 2020 and again in early February 2020. The following section describes each of the three tools in detail.

The first tool, the facility assessment, is comprised of seven sections. The first section collected background information on the facility, including the GPS location, the type of facility, information about the opening hours, and about the facility's infrastructure (e.g. is there a pharmacy, is there a power supply, and is there a running water supply). The second short

section recorded information about the levels of staffing in the facility. In the third section, providers indicated the volume of patients that the facility treated in the last three months, and also described the kinds of services the facility provides. Next, enumerators were trained to determine the availability and test the functionality of several basic pieces of equipment (e.g. a weighing scale, a thermometer, and a sphygmomanometer). Another section collected information on the infection and waste management processes employed at the facility. The sixth section, on immunization services, determined whether relevant supplies to support vaccination were present (e.g. sharps container, immunization cards, and a refrigerator). The final section collected information about the availability of general drugs, key drugs for maternal and child health, and vaccines. This list of drugs was informed by Bihar's List of Essential Medicines for use at PHCs (Government of Bihar 2018). Other questions and the structure of the tool were informed by the Service Provision Assessment (SPA) and the Service Availability and Readiness Assessments (SARA) tools (The DHS Program n.d.; World Health Organization 2014).

Clinical vignettes were the second tool employed to assess process quality via the knowledge of providers in rural Bihar. Four vignettes were developed to assess provider skills: one on diagnosing a new case of hypertension and initiating first-line treatment, one on diagnosing a simple case of childhood diarrhea and prescribing oral rehydration salts (ORS), one on diagnosing childhood pneumonia and prescribing antibiotics, and a final vignette on recognizing a case of angina and starting treatment with nitrates and immediately referring to a higher level of hospital. Each vignette employed one enumerator who pretended to be the patient (or the patient's mother) presenting to the clinic and answering questions about the condition, and another enumerator who recorded the provider's stated actions in a structured data collection

form. The data collection tool first collected background information about the health worker, including the age, sex, religion, and caste of the provider. It also collected information about the provider's medical training, current residence, involvement in practitioner groups, and whether they had treated anyone with chronic conditions (and later COVID-19) in the last 6 months. The tool followed a standard format for each of the four vignettes: first the case was presented to the provider. Next the provider was prompted to ask all of the questions they would normally ask to take the patient's history. During this section, the enumerator pretending to be a patient was trained to respond to provider questions in a standardized way. The following section on examinations recorded information on the tests that the provider would perform based on the previous answers from the history-taking section. The patient-enumerator also gave standardized responses to explain the results of each of the examinations. The provider was then asked to make a diagnosis based on the previous information. Based on this diagnosis, the provider was prompted to make a judgement about whether referral or a follow-up appointment were necessary. The provider was also asked which medicines she would prescribe (the name, dose, frequency, and duration of the prescription were recorded) and what additional advice the provider would give the patient, including any danger signs the patient should watch out for. The development of each of the four vignettes was informed by previously designed and validated tools with the input of local and specialist physicians. Specifically, the pneumonia and diarrhea vignettes had been previously validated and used in the Indian context, while the hypertension and angina vignettes were developed with substantial input from cardiologists to address India's shifting burden of disease. (Das and Hammer 2005).

The third component of the provider assessment, the patient observation tool, was designed to test the existence of a know-do gap in clinicians under study. Thus, its design closely mirrored the structure of the clinical vignettes. After receiving a patient's consent to participate in the study, the tool took information on the patient's age, sex, and primary and secondary complaints. If the age and complaint matched the characteristics of the clinical vignettes (i.e. an adult with high blood pressure or angina or a child with diarrhea or cough) then the tool was modeled after the clinical vignette form, and enumerators recorded all history taking questions asked by the provider, examinations conducted, and diagnoses made. For other patient types, a standard patient observation form was used to record questions asked by the provider about duration and severity of illness and additional symptoms, as well as generic tests performed such as blood pressure measurement and checking temperature. For all patient observations, the enumerator recorded whether the provider told the patient the name of their illness, explained the cause of the illness, precautions to take at home, potential danger signs, and whether a prescription was made. After patients left the office, enumerators reviewed the patient's prescription script and recorded information about the diagnosis, and the name, dose, frequency, and duration of the drug(s) prescribed. The duration of the consultation was also recorded.

Data Collection

Fieldwork for the second phase of data collection was led by OPM and conducted by ten enumerators, three supervisors, and one central supervisor. Five of the enumerators were qualified nurses with clinical and research experience, and five of the enumerators were graduates in the social sciences with previous experience conducting facility surveys. Nurse enumerators and non-nurse enumerators paired up to implement the data collection. Nurse

enumerators were the moderators during the clinical vignettes and led the data collection during the facility assessment and patient observations. The non-nurse enumerators pretended to be the patient during the clinical vignettes and played a supporting role during the facility assessment and patient observations (e.g. finding sphygmomanometers and other equipment, copying patient prescription scripts, and providing other general assistance). Three to four pairs of enumerators were supervised by a more experienced OPM employee, who assisted in the overall coordination of data collection by finding providers based on GPS locations recorded during Phase I, fixing appointments with providers, and answering questions and allaying concerns about the study (usually from informal providers). The supervisors also observed surveys and conducted spot checks on the collected data to validate answers to key questions with 20% of the providers. Central supervisors overseeing the entire data collection process also visited field sites with teams to provide oversight twice weekly.

Teams were trained over the course of ten days in February 2020 and a seven-day refresher training was conducted in February 2021. The training consisted of sessions on the purpose of the study, how to correctly use the survey tool on electronic tablets using the CAPI software, and four days of field practice before the start of data collection. Written consent to participate in the survey was obtained from all providers and from patients who were observed during patient-provider interactions. Daily debriefing sessions were conducted across the field survey teams and errors or difficulties were reported to the central supervisors. Twice a week, all of the supervisors had a call with the Johns Hopkins team to discuss any issues. At the end of each day, data was automatically uploaded to a central server from all of the tablets. This data was automatically run

through a logic-checking do-file in Stata, and any outliers, unusual data, or missing data were flagged and checked with supervisors and enumerators to ensure accuracy of collected data.

There were no issues with use of the facility assessment tool or the clinical vignettes. Supervisors proactively reached out to providers to schedule interviews to minimize disruption during patient consultation hours and maximize provider response rates. Although the study was designed to observe five patient interactions during each facility visit, this became a major bottleneck for survey implementation. Many of the providers that were visited did not receive five patients throughout the course of an entire day, which left enumerators idle for hours after completing the facility assessment and the clinical vignettes. To solve this problem, we adjusted the survey protocol to apply the patient observation tool to all patient interactions that occurred over the course of three hours at the clinic. This ensured that enumerators could complete all tools for at least two providers per day.

Data collection started on February 18, 2020 and was halted on March 13, 2020 due to the COVID-19 outbreak. During the first phase of data collection, providers from 28 out of the 70 selected villages were sampled (40% of envisioned sample). Data collection was completed in the remaining villages between February 22, 2021 and March 15, 2021, however the patient observations were not conducted when data collection resumed in 2021 due to concerns over enumerator safety during the ongoing COVID-19 pandemic. In total, facility assessments and clinical vignettes were administered to providers in the 70 villages that were selected for data collection and patient observations were conducted with providers in 28 of these villages.

There were 502 unique providers utilized by individuals from the 70 selected villages in the household survey and located by the GPS team. Of these providers, 390 were reached for the provider assessment (76.4%). This compares favorably with the provider response rate from a previous study in India with similar study design, which reported a response rate of 41.9% among local providers (Das et al. 2020). Vignettes and facility assessments were conducted for all 390 providers, but there was variation in the number of patient observations across providers. In total, 377 patient interactions were observed across 110 providers in 28 villages. Among the 168 providers included in the 2020 data collection, the average number of patient observations was 2.2 per provider and ranged from 0 to 6 observations per provider. There were fewer patient observations at private providers than public providers. Even though 17.2% of the sampled providers were public facilities in the 2020 data collection, 34.2% of patient observations were recorded in public facilities.

The final sample included 390 providers for whom the facility assessment and clinical vignettes were conducted. The sample included 47 PHCs, 23 CHCs (that functioned as a PHC), 1 District hospital, 314 private clinics, and 5 private hospitals. The primary reason for non-response was that providers were not available when enumerators were at the village for data collection. This was mostly because providers maintained seasonal or limited hours during certain days of the week. Whenever possible, appointments were made to ensure provider availability and to ensure that the provider was not rushed during data collection.

Analysis

All data was collected via tablets and automatically uploaded to a central server through the CAPI application. As data was uploaded to a central server, OPM staff translated the data into a Stata dataset, on which several quality checks were routinely conducted to flag outliers and questionable values for supervisors to check with enumerators. The methodology to obtain state-representative estimates of provider quality differed by provider type. Sample weights were applied to obtain state-representative estimates for PHC-related quality of care but since there was no census of private providers, it is impossible to determine state-representative estimates for quality domains in the private sector.

Ethics and Author's Contributions

The project was a collaboration between Johns Hopkins University, CARE India, and Oxford Policy Management, and was funded by the Bill and Melinda Gates Foundation under the BTSP. The Assessment of Primary Health Care System in Bihar study was approved for human subjects research by the Johns Hopkins University Institutional Review Board (IRB00009563). It was also approved by the Sigma Institutional Review Board in India (Doc#'s 1910787106 / 1910789424). The principle investigator was Dr. Krishna Rao and other JHSPH faculty members on the project team included Dr. Henry Perry, Dr. David Bishai, Japneet Kaur, and Niketa Pawar. Contributing JHSPH graduate students included Caitlin Noonan (2020 MSPH graduate, Health Systems program), Onaopemipo Abiodun (PhD candidate, Health Systems Program), Hunied Kautsar (2021 MSPH graduate, Health Systems Program), and Joseph Millward (2020 MHS graduate, Health Systems Program). Additional members of the project team included Navneet Kumar (Oxford Policy Management), Bhavna Seth (Johns Hopkins School of

Medicine), and Satbir Kaur (Indian Institute of Health Management Research/ Johns Hopkins Bloomberg School of Public Health). All study investigators completed training in human subjects research and have declared no conflicts of interest.

The author of this dissertation joined the Assessment of Primary Health Care System in Bihar Study as a research assistant in September 2019. The author was closely involved all phases of the project, and played a lead role in designing and planning the household survey, developing tools (especially the chronic disease module in the Phase I study and the hypertension vignette in the Phase II study), translating tools to CAPI software, conducting pilot tests, participating in enumerator trainings, supervising data collection, cleaning data, performing analysis, and disseminating results. This has included three field visits to Bihar in September 2019, November 2019, and January through February 2020.

During the onset of the COVID-19 outbreak, the author participated in a research effort to leverage the network of providers identified in the Assessment of Primary Health Care System in Bihar Study to support the Government of Bihar's COVID-19 response. A rapid telephonic survey was conducted to assess provider knowledge, attitudes, and practices towards COVID-19 treatment and the results were shared with the government and published (Rao et al. 2021). The author has also continued to support local Bihari researchers in publishing their work and to support CARE India with technical assistance in designing evaluations and conducting relevant research as needed to support the larger BTSP (e.g. on non-communicable diseases and on urban health in Bihar).

Outline for Subsequent Sections

The remaining chapters of this thesis describe how the findings from this study are applied to improve the measurement of effective coverage for services to manage hypertension. Chapters two through four can be read as standalone publications and may repeat key definitions, assumptions, and findings that appear elsewhere. The second chapter reviews the existing evidence on measuring effective coverage of hypertension management services through a scoping review and proposes a framework to address current gaps in the conceptualization of effective coverage and assist in future measurement efforts. The third chapter applies the framework to rural Bihar, India to demonstrate key barriers to achieving effective hypertension management. Chapter four proposes and calculates a single metric for measuring effective coverage of hypertension management services, drawing on lessons from the previously designed framework and its application. The final chapter presents the policy relevance, future areas for research, and concluding thoughts generated by this dissertation.

Chapter 2: The Expanded Hypertension Care Cascade

A scoping review to improve effective coverage of hypertension management services in low- and middle-income countries

Abstract

Background: With the steadily rising burden of hypertension in low- and middle-income countries (LMICs), there is an urgent need to measure the coverage of health services that effectively manage blood pressure. However, there is little agreement on how to define effective coverage and the existing hypertension care cascade (hypertension prevalence, percent aware, percent treated, and percent controlled) does not account for the quality of services provided.

Methods: A systematic scoping review of published literature was used to identify studies that defined effective coverage of hypertension management services or incorporated dimensions of service quality into population coverage measures. These findings were used to inform an expanded hypertension care cascade from which quality-adjusted coverage can be calculated.

Results: The review identified 20 relevant studies, including 8 which defined effective coverage for hypertension management services and 12 that reported a measure of service quality in a population-based study. Based on commonly reported barriers to hypertension management, new steps on the proposed expanded care cascade include (i) percent screened, (ii) percent linked to quality care, and (iii) percent adhering to quality treatment.

Conclusions: There is little consensus on the definition of effective coverage of hypertension management services, and most studies do not describe the quality of hypertension management services provided to populations. Incorporating key aspects of service quality to the hypertension cascade of care allows for the calculation of quality-adjusted coverage of relevant services, enabling the appropriate measurement of health systems performance.

Background

Optimally organized health systems provide people with access to needed health services without causing financial hardships, but unless these services are of a certain level of quality, they may not improve population health. It is widely accepted that expanding the coverage of health services alone is not sufficient to improve population health for maternal and child health interventions (Tanahashi 1978; Hannah H Leslie et al. 2017). Without considering service quality, measurements of service coverage, also known as "crude coverage", are only weakly associated with the health benefits received by a population (Amouzou et al. 2019). Effective coverage is a promising metric for evaluating program and health system performance because it captures whether individuals are receiving health services of sufficient quality to achieve the health improvements that are possible from medical and behavioral interventions (Ng et al. 2014). Effective coverage of key health services has been adopted by the World Health Organization (WHO) and the World Bank as a metric for monitoring progress towards universal health coverage, and therefore for measuring health system performance globally.

Despite the promise of effective coverage, there is not yet consensus on how to operationalize its measurement. An initial paper described six methods for calculating effective coverage and a recent scoping review found that at least four of these approaches have been adopted to measure intervention quality and calculate effective coverage, ranging from tracking changes in biomarkers to using statistical (Table 2.1) (Ng et al. 2014; Jannati et al. 2018).

Table 2.1: Approaches to calculate effective coverage

Approach	Description	Study examples	Potential data sources	Strengths	Limitations
Content of care	Focuses on the health care process Involves indicators that target the resource and activity outputs of an intervention	Effective coverage of primary health care services in 8 countries (Hannah H Leslie et al. 2017)	Direct observation or clinical vignettes Hospital databases Patient exit interviews	Offers information from both demand- and supply-side factors Resource and activity outputs can serve as objective indicators	Subjectivity in patient assessments of quality High outputs or content of care may not directly translate into health gains
Biomarkers	Focuses on the health benefits that can be detected biologically	Assessment of vaccine effectiveness (Pebody et al. 2002)	Health surveys that include physical examinations	Provides an objective measure of actual health gains or impact	Collection of biomarker data can be costly and not always feasible in resource-constrained settings Not applicable to all health conditions
Cohort registration	Focuses on changes in individual health outcomes over the course of treatment	Assessment of highly active antiretroviral therapy (HAART) (Sterne et al. 2005)	Cohort registration databases	Provides measurement of treatment effectiveness for chronic conditions over time	Limited to interventions that involve close patient monitoring and treatment by healthcare providers Requires careful consideration of time-dependent confounding factors and lost to follow-up
Exposure matching	Compares health outcomes of individuals who had intervention exposure to those who did not have exposure to an intervention	Assessment of health impact of IPTp and ITNs (Eisele et al. 2012)	Household survey data	Allows for the quantification of the health gains associated with intervention exposure by calculating odds ratios or relative risks with existing data	Household surveys are rarely powered to detect health effects Unmeasured confounding factors need to be accounted for due to the observational nature of analysis
Statistical methods	Uses statistical and econometric techniques, such as instrumental variables and matching, to estimate health outcomes while controlling for unobserved variables	Assessment of diabetes and hypertension management in Iran (Farzadfar et al. 2012)	Health survey data	Offers a convenient solution to address potential biases associated with confounding factors	Only approximates the relationship, or correlation, between intervention exposure and a health outcome rather than the causal effect
Risk-adjusted outcomes	Estimates health outcomes while accounting for the patient characteristics and risks of death that can vary systematically across sites	Birth weight–adjusted neonatal mortality (Straney, Lim, and Murray 2012)	Hospital databases	Provides an indicator for quality of care that reflects both procedural outputs and the health impact of received care	Limited to interventions that are delivered at health facilities- Certain risks may not be easily adjusted for if they are challenging to quantify

Adapted from (Ng et al. 2014)

Previous studies have calculated effective coverage by adjusting intervention coverage levels according to a level of intervention quality, such as service readiness, quality of care provided, or health outcomes achieved (Nguhiu, Barasa, and Chuma 2017; Marsh et al. 2020; Colson et al. 2015; Hannah H Leslie et al. 2017). The Institute for Health Metrics and Evaluation (IHME) has approximated effective coverage by modeling outcome-based measures across populations and the WHO is developing new weighting methods to further advance coverage estimates based on modelled health outcomes (World Health Organization 2020; Lozano and GBD 2019 Universal Health Coverage Collaborators 2020). Working within these global measurement frameworks, national and sub-national efforts to calculate effective coverage of services primarily focus on health outcomes as a measure of intervention quality. While this approach has the benefit of providing an estimate of the health gains directly experienced by populations, many factors beyond the reach of the health system can influence health outcomes. These factors, or social determinants of health, are interrelated issues which influence health including social status, early life exposures, employment, social support and/or exclusion, and stress (Marmot 2005). Measures of effective coverage that only incorporate health outcomes capture the impact of these social determinants and therefore may not reflect the direct contributions of health system performance to improving population health. Methods for calculating effective coverage that consider the quality of services provided by the health system address this shortcoming.

Incorporating appropriate measures of service quality[4] into effective coverage calculations is challenging. Quality in healthcare has been conceptualized as consisting of three parts: structure, related to the settings in which care occurs; process, what is actually done to provide care; and outcomes, the effects of care on the health status of patients and populations (Donabedian 1966,

[4] In this study, service quality primarily refers to structure and process quality

1988). All three of these quality components influence the effective coverage of interventions to some extent (Box 2.1) (Amouzou et al. 2019). While structural quality is conceptualized as a necessary precondition to good quality care, studies have demonstrated that it is poorly correlated with provision of evidence-based care in low- and middle-income countries (Hannah H Leslie, Sun, and Kruk 2017; Hodgins and D'Agostino 2014). As previously mentioned, outcome measures of quality may not adequately capture health system performance due to the substantial impact of social determinants on health outcomes. Increasingly, measuring the processes of care provided and their impact is being recognized as vital for assessing health systems performance (Bilimoria 2015; Akachi and Kruk 2017; Kruk et al. 2018).

Box 2.1: Quality components that inhibit effective coverage of health services

Structure
- Lack of service availability
- Insufficient equipment and medicines

Process
- Providers do not follow standards of clinical care
- Patients do not adhere to recommended treatment

Outcomes
- Low patient satisfaction
- Sub-optimal intervention efficacy

For some interventions, it is relatively easy to measure aspects of process quality that will result in improved health [e.g., determining whether a child received three doses of diphtheria, tetanus, and pertussis (DTP) vaccine according to an immunization schedule]. In these cases, there are obvious solutions for adjusting contact coverage measures to arrive at estimates of effective coverage (e.g., measuring the percent of population covered by one dose of DTP versus the percent of population covered by three doses of DTP). For other health services, such as those to

diagnose and manage hypertension, the processes that should be included in effective coverage measurements are less clearly defined.

Hypertension, or raised blood pressure[5], is a leading cause of global cardiovascular mortality and morbidity, which causes a third of all deaths globally (Zhou et al. 2017). Between 2000 and 2010, the age-standardized prevalence of hypertension fell by 2.6% in high-income countries, but rose by 7.7% in low- and middle-income countries, demonstrating the need for increased attention to hypertension management in these settings (Mills et al. 2016). Hypertension can be controlled at the primary care level with a combination of sustained lifestyle changes and relatively affordable pharmaceutical options, however successful treatment requires continuous monitoring and interaction with the health system. Successful management of hypertension at the population level is indicative of strong health system provision of preventive and curative services. Therefore, measuring the coverage of hypertension management services[6] that result in sustained non-elevated blood pressure levels, or the effective coverage of hypertension management services, can indicate health system performance.

Population-level progress towards controlled blood pressure has been measured in a more or less standard way in the US and internationally since at least the 1980s using a cascade of care framework (Cummings et al. 1982; National Heart Blood and Lung Institute 1985; Chadha et al.

[5] Specifically, hypertension is defined as a systolic blood pressure of 140 mm Hg or more and/or diastolic blood pressure of 90 mm Hg or more and/or taking antihypertensive medication

[6] Hypertension management services include all of the services that result in sustained non-elevated blood pressure levels, including screening and early detection/diagnosis, counseling on lifestyle modifications, prescribing antihypertensive medications, monitoring effectiveness of treatment, and continuing interactions between providers and patients.

1990). The cascade of care usually involves measuring blood pressure levels of individuals sampled in a population-based survey and recording:

(i) the prevalence of blood pressure (based on elevated blood pressure readings on the day of the survey or reported use of antihypertensive medicine),

(ii) the awareness of hypertension (the percent of those classified as hypertensive who had been previously diagnosed by a health worker),

(iii) the treatment of hypertension (the percent of hypertensives who report recently taking antihypertensive medicines), and

(iv) the control of hypertension (the percent of those who report taking antihypertensive medication and have non-elevated pressure on the day of the survey).

This standard hypertension cascade of care, measured at the population level, has enabled several powerful systematic reviews and meta-analyses on hypertension management in countries, regions, and globally (Bosu 2010; Mills et al. 2016; Zhou et al. 2017; Geldsetzer et al. 2019; Akl et al. 2020). However, the hypertension cascade of care does not account for the quality of health services that contribute to improved health. For other, mostly maternal and child health interventions, cascades of care have been expanded to account for process quality, which are used in turn to measure effective coverage (Amouzou et al. 2019; Marsh et al. 2020). The absence of process quality-related indicators in the hypertension cascade of care prohibits its ability to adequately measure health system performance related to hypertension care.

While the existing hypertension cascade of care framework does incorporate a key measure of outcome quality (the percent of those who report taking antihypertensive medication and have

non-elevated pressure on the day of the survey), process quality measures are needed to fully understand the role of the health system in achieving population blood pressure control. Without understanding the coverage of quality-adjusted services and examining relevant inputs and processes, health services research may not reveal the drivers of and barriers to successful hypertension management and improved health. Thus, supply-side factors should be considered and incorporated within the hypertension cascade of care. This scoping review study seeks to review definitions of effective coverage for hypertension management services, including how non-outcome quality measures have been incorporated into studies that examine the hypertension cascade of care in low- and middle-income countries. Based on these findings, improvements to the cascade of care framework will be proposed to inform improved measures of effective coverage of hypertension management services. A scoping study methodology is the correct approach for this research question, as it is a broader topic where many different study designs might be applicable (Arksey and O'Malley 2005; Munn et al. 2018).

Methods

The study followed Arksey and O'Malley's process for conducting a scoping review, incorporating subsequent methodological advancements (Arksey and O'Malley 2005; Levac, Colquhoun, and O'Brien 2010). One overarching research question was identified, specifically "how have measures of coverage of hypertension management services in low- and middle-income countries considered aspects of service quality?" To find relevant studies, we performed a search of electronic journals and databases including Scopus, EMBASE, PubMed, ScienceDirect, ProQuest, and Web of Science using keywords "hypertension" and "effective coverage" or "cascade of care" and its variants. An additional search was conducted in a subset

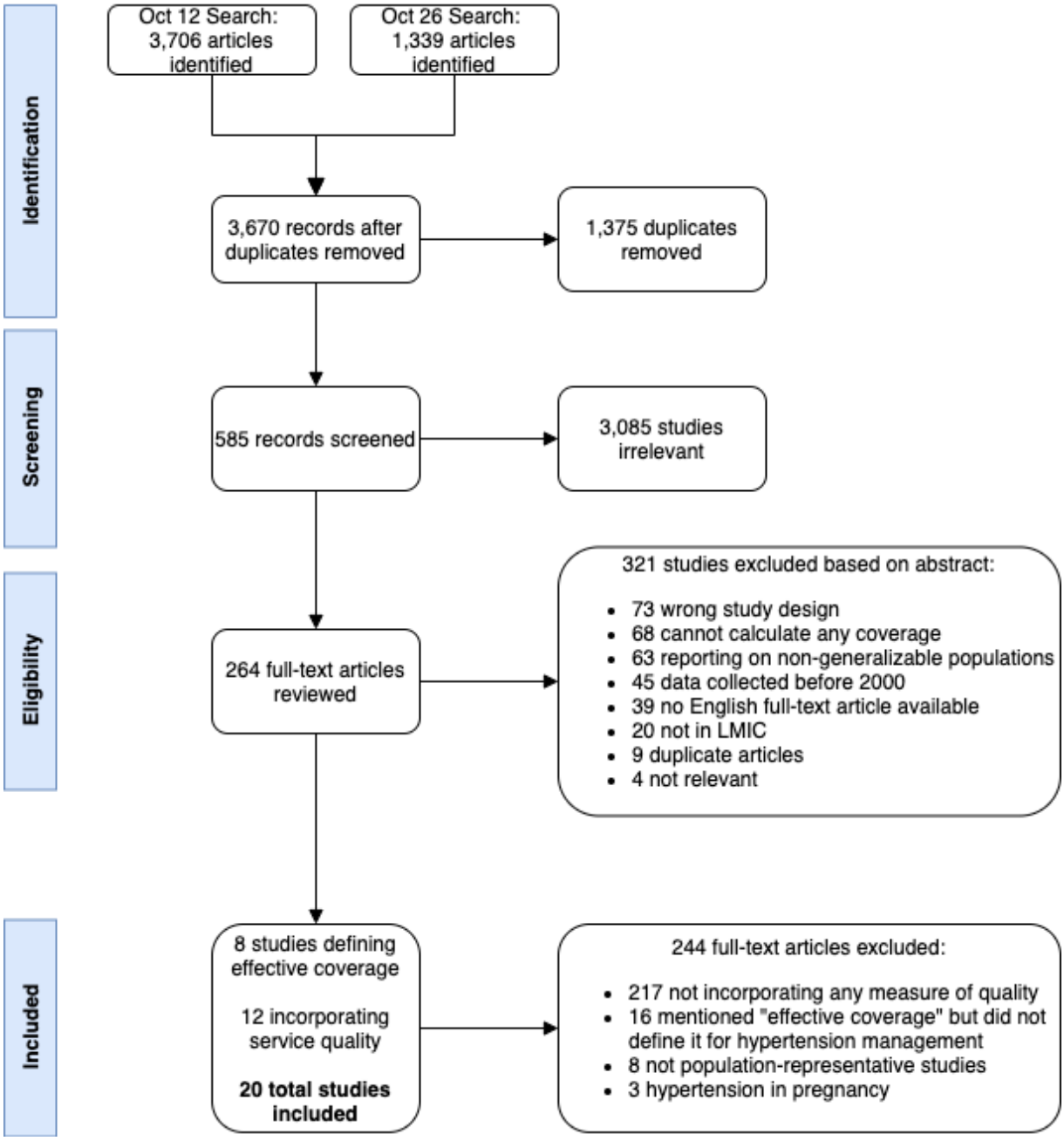
of databases to include published studies that included aspects of hypertension management (e.g. prevalence, treatment, and control) but did not mention the care cascade by name (see Annex 2 for search strategy). The search strategy was calibrated to ensure that three pre-identified "tracer" articles which discussed effective coverage of hypertension management services were included in results (Lozano et al. 2006; Liu et al. 2008; Charoendee et al. 2018). These searches were conducted on 12 and 26 October 2020 and were supplemented by periodic searches of grey literature databases and suggestions from experts to include additional information. Titles and abstracts of articles were collated, duplicates were removed, and titles and abstracts were screened for relevance in the Cochrane Community's screening and data extraction tool, Covidence (Veritas Health Innovation, n.d.). Relevant studies identified through title and abstract screening included those that (i) mentioned hypertension in the title, (ii) were conducted in a low- or middle-income country according to 2018 World Bank classifications, (iii) reported data collected since 2000, (iv) were associated with a full text manuscript in English (conference abstracts and commentaries were excluded but corresponding authors were contacted when possible), (v) used a population-representative study design (which is necessary to calculate coverage of a service in the general population), and (vi) reported sufficient information to calculate coverage. Any relevant study that mentioned "effective coverage" in the title or abstract was automatically included in the full text review. Studies were excluded during the full-text review if they (i) did not report any measure of service quality, (ii) reported on quality of care for pregnancy-related hypertension, (iii) reported on specific populations (not age-related) that preclude generalization to entire populations, or (iv) included the words "effective coverage" but did not define the concept specifically for hypertension management services. The full text of selected studies was reviewed and relevant information (on study type, data sources, definition of

effective coverage, incorporation of service quality, among others) was extracted in an online survey platform, Qualtrics ("Qualtrics" 2005). At the title and abstract screening and full-text review stages, two reviewers examined each article, and conflicts were discussed and resolved by the study leader. Findings were summarized in tables that demonstrated (i) how "effective coverage" of hypertension management has been defined, and (ii) how dimensions of service quality have been incorporated into studies reporting population-level coverage of hypertension management services. The quality of included articles was assessed using the Appraisal tool for Cross-Sectional Studies (Annex 3) (Downes et al. 2016). Findings were used to propose additional steps on the hypertension care cascade, including methods to improve the measurement of effective coverage for health systems performance evaluation. Finally, the revised framework was shared with experts on effective coverage and hypertension management experts and feedback was incorporated to improve the overall framework.

Results

Across the databases, 5,045 records were identified, including 3,670 unique records which were screened for relevance. After title and abstract screening, 585 relevant records were assessed for eligibility for full-text review. Of these, 264 full-text records were reviewed and 20 records were included that defined effective coverage of hypertension services (n=8) or incorporated measures of service quality into their findings (n=12) (Figure 2.1).

Figure 2.1: PRISMA review flow chart



There were eight reviewed records which defined effective coverage of services related to hypertension management (Table 2.2).

Table 2.2: Definitions of effective coverage of services to measure hypertension

Author, year	Study Type/Data source	Study population	Definition of Effective Coverage	Quality Measure Reported		Effective vs Crude Coverage
(Lozano et al. 2006)	Sequential cross-sectional Instrumental variable analysis National survey in 2005-2006	Mexico, nationwide Adults over 20 years old	The ratio of actual reduction in systolic blood pressure to the difference between pretreatment systolic blood pressure and the target blood pressure for all individuals with hypertension (i.e., the proportion of the population reduction in blood pressure that can potentially be delivered through treatment that is actually delivered).	Outcome quality Reduction in systolic blood pressure compared with treatment targets		Nationally, crude coverage of hypertension treatment is estimated to be about 49% while effective coverage is only 23%
(Liu et al. 2008)	Cross-sectional 2004 China Adult Chronic Diseases Risk Factors Surveillance Survey	China, nationwide Adults age 18-69	Percentage of hypertensive people who reported having taken control measures and whose blood pressure was normal during the survey period	Outcome quality Normal blood pressure during the survey period		Treatment coverage was 26.7% Effective coverage was 8.9%
(Charoendee et al. 2018)	Cross-sectional Administrative data from outpatient services collected in 2013	Thailand, 76 provinces outside of Bangkok Population aged 15 years and older	The percent of population that receives appropriate hypertension screening and/or treatment based on their needs	Normo-tension	Process quality Received at least one BP measurement	Crude coverage was 54.6% Effective coverage was 49.9% Difference between crude and effective coverage ranged from 6.9% to 80.5% between provinces
				Pre-hypertension	Process quality Received HT and CVD risk assessment	
				Suspected hypertension	Process quality Received repeat BP measurement within 2 months of initial screening	
					Process quality Received CVD risk assessment	
				Newly diagnosed hypertension	Process quality	

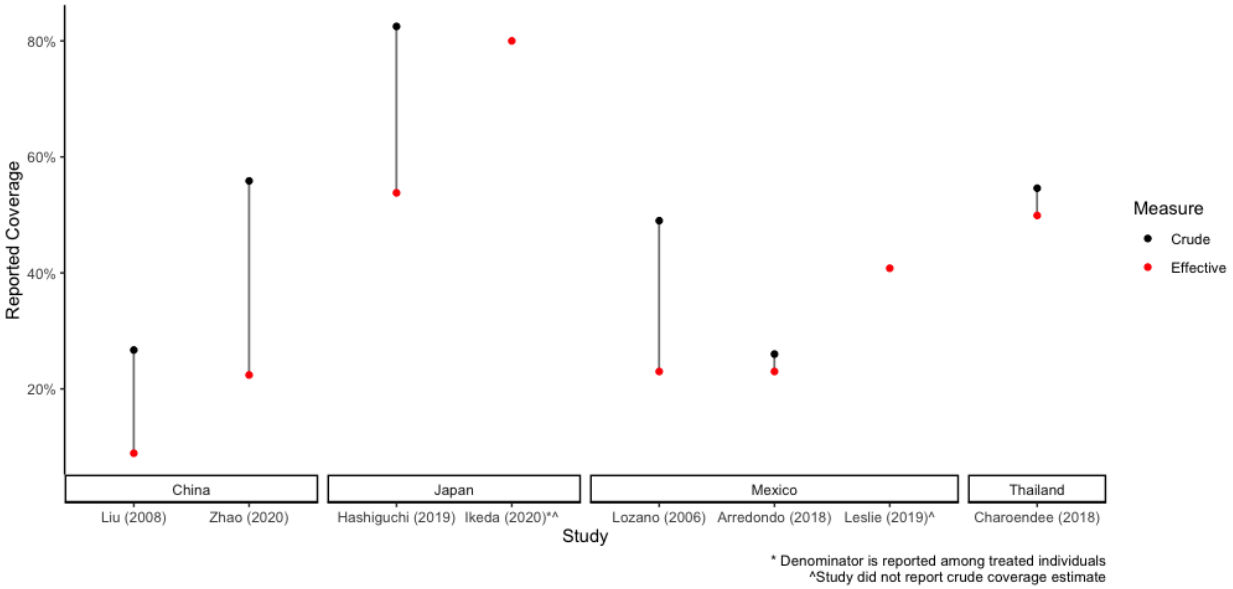
Author, year	Study Type/Data source	Study population	Definition of Effective Coverage	Quality Measure Reported		Effective vs Crude Coverage
					Received early treatment	
					Outcome quality Blood pressure lower than initial level or under control with serum lipid level better than initial test	
(Arredondo, Azar, and Recaman 2018)	Sequential cross-sectional Records of effective use of health services in 2005 and 2015	Mexico, selected states	Effective universal coverage is the proportion of patients that effectively received care after demanding services to the health system for the control of hypertension	Outcome quality Controlled blood pressure		National crude coverage was 26% National effective coverage was 23%
(Hashiguchi et al. 2019)	Cross-sectional General medical examinations, personnel information, and medical expense claims	Japan, employees in a company group	Number with effective control / Number needing treatment	Outcome quality Percentage who show therapeutic effects (reduced blood pressure) among those who use medical services		Crude coverage was 82.5% Effective coverage was 53.8%
(H H Leslie, Doubova, and Pérez-Cuevas 2019)	Cross-sectional 2012 Mexican National Health and Nutrition Survey National health information system	Mexico, nationwide	Proportion of individuals in need who experience potential health gains	Outcome quality Blood pressure tests<140/90 among patients with hypertension Outcome quality Patients with hypertension without hypertension-related hospitalization in past year		National effective coverage was 40.8%
(Y Zhao et al. 2020)	Longitudinal Population based surveys in 2011 and 2013 with biomarkers	China, nationwide Adults over age 45	The fraction of blood pressure reduction that is delivered to the population who take the anti-hypertensive medication	Outcome quality Actual reduction in systolic blood pressure and/or diastolic blood pressure through taking antihypertensive medication from 2011 to 2013 as measured in the CHARLS surveys		Treatment coverage: 55.86% Effective coverage: 22.4%

Author, year	Study Type/Data source	Study population	Definition of Effective Coverage	Quality Measure Reported	Effective vs Crude Coverage
(Ikeda et al. 2020)	Sequential cross-sectional Nearest-neighbor matching on 15 annual Japanese National Health and Nutrition Surveys (2003–2017)	Japan, nationwide Adults 40-74 years	Ratio of actual reductions in biomarkers to potential reductions that could be delivered for individuals receiving treatment. Denominator is treated individuals instead of all individuals in need	Outcome quality Averaged the differences between observed and counterfactual blood pressure levels among treated participants to estimate average treatment effects on the treated	Effective coverage (among those treated) increased from 55.7% in 2003-2007 to 80.0% in 2013-2017

These studies took place in Mexico, China, Japan, and Thailand and were published between 2006 and 2020. Among the six studies that reported crude and effective coverage, the average difference in coverage estimate was 18.9% (Figure 2.2). All eight of the studies reported some measure of outcome quality in their definition of effective coverage, however there were differences in the way effective coverage was operationalized. Definitions of effective coverage included the ratio of actual reduction in blood pressure over target reduction (Lozano et al. 2006), the percent of the hypertensive population achieving blood pressure control (Hashiguchi et al. 2019), and the percent of the hypertensive population experiencing potential health gains (hypertension-related hospitalization) (H H Leslie, Doubova, and Pérez-Cuevas 2019). Three of the studies defined effective coverage for hypertension management services among other health services within the context of evaluating health systems performance (Lozano et al. 2006; Liu et al. 2008; H H Leslie, Doubova, and Pérez-Cuevas 2019). Two studies defined effective coverage for hypertension management alongside other chronic diseases, namely diabetes and dyslipidemia (Hashiguchi et al. 2019; Ikeda et al. 2020). One study considered a package of hypertension screening-related interventions and defined effective coverage for individual aspects of a national hypertension screening program (Charoendee et al. 2018). Cross-sectional

data sources were used in the majority of studies (7 out of 8), and longitudinal data sources were used in one study (Y Zhao et al. 2020). Out of the eight studies, only one study reported any quality measure other than outcome quality, and reported process quality indicators on what kinds of screening-related services were received by certain population segments in need (Charoendee et al. 2018).

Figure 2.2: Reported differences in crude and effective coverage of hypertension management services



In addition to the records that defined effective coverage for hypertension management services, there were 12 studies that considered coverage of these services adjusted for aspects of service quality (Table 2.3). These studies were published between 2007 and 2020 and took place across 9 countries: Bangladesh, Brazil, Cuba, India, Kenya, South Africa, Tajikistan, Tanzania, and Uganda. Only one study was representative at the national level (Macinko, Leventhal, and Lima-Costa 2018). Eight studies incorporated measures of process quality and seven studies incorporated measures of structural quality (some studies described measures of both process and structural quality).

Table 2.3: Studies that incorporate service quality into measures of coverage

Author, year	Study Type/Data source	Study population	Cascade of Care	Quality Measure Reported	Notes
(Thorogood et al. 2007)	Mixed-methods (cross-sectional) Household survey, rapid ethnographic assessment including interviews, focus groups, and participatory techniques	South Africa: 1 sub-district (Agincourt) Adults 35 or older	Not explicitly defined	Structural quality Availability of drugs in clinics (stock outs) Clinics either had to deny treatment to patients or switch treatment to another drug- both were likely to reduce adherence Lack of appropriate equipment (none were in satisfactory condition)	Hypertension management was studied in the context of the burden of stroke
(Khanam et al. 2014)	Cross-sectional Household survey (no biomarkers)	Bangladesh: three rural sites (Matlab, Abhoynagar, and Mirsarai) Individuals aged 25 and above	Not explicitly defined	Process quality: Diagnosis by a qualified doctor Adherence to treatment	Only about half of people with self-reported hypertension were diagnosed by qualified doctors. 26.2% of hypertensives were non-adherent to treatment
(Bhandari, Sarma, and Thankappan 2015)	Cross-sectional Household survey	India: Urban slum dwellers in Kolkata Hypertensive patients aged 25 and older	Prevalence of ISH Awareness of ISH Compliance to medication Controlled blood pressure	Structural quality: Availability of medications Process quality: Adherence to medication in the past week Adherence to lifestyle modification advice (physical activity and salt restriction) Outcome quality: Patient satisfaction	All quality measures are based on self-report Patients adherent to prescribed medications were 2 times more likely to achieve blood pressure control than those who were not
(Zack et al. 2016)	Longitudinal Household survey	Tanzania: peri-urban area near Dar es Salaam Hypertensives 40 years or older	Percent of hypertensives diagnosed Percent of hypertensives receiving treatment Percent of hypertensives with controlled blood pressure	Process quality: Accessing health professional for follow up Adherence to medication	All quality measures are based on self-report
(Gabert et al. 2017)	Mixed-methods (cross-sectional) Household and health facility surveys, focus group discussions, interviews	India: 2 Districts (Shimla and Udaipur) Individuals aged 15 and above	Percent of hypertensives diagnosed Percent of hypertensives receiving treatment Percent of hypertensives with controlled blood pressure	Structural quality: Perceived lack of diagnostic equipment and testing capabilities (demand side) Patients were referred to private institutions or higher levels of care, stockouts were frequent, not enough time to counsel patients (supply side) Gaps in availability of diagnostic equipment and pharmaceutical supplies	Used a linked survey study design Poor description of results (text does not match the tables)
(Galson et al. 2017)	Mixed-methods (cross-sectional) Household survey and focus group discussions and interviews with	Tanzania: Kilimanjaro region Adults 18 or older	Not explicitly defined	Structural quality: Long wait times, understaffing, lack of experience, and medication costs Outcome quality: Perceived quality of biomedical healthcare delivery	A cascade of care was not explicitly defined, but the study accounted for the type of treatment received by hypertensives (biomedicine or traditional medicine)

Author, year	Study Type/Data source	Study population	Cascade of Care	Quality Measure Reported	Notes
	patients and providers				
(Macinko, Leventhal, and Lima-Costa 2018)	Cross-sectional data National Health Survey	Brazil, national Adults 18 or older	Contact with the health system Diagnosis Receipt of treatment Receipt of continuous, high-quality hypertension-related care Blood pressure control and reduction of complications and/or physical limitations	Process quality: Continuous, high-quality care was defined as reporting no financial or organizational barriers to accessing hypertension-related healthcare, reporting that laboratory/diagnostic examinations were requested, that the provider knew about results of any diagnostics or lab-oratory exams (if requested), and receipt of all health advice	All quality measures are based on self-report
(Wollum et al. 2018)	Mixed-methods (cross-sectional) National household data, health facility surveys, focus group discussions, and key informant interviews	South Africa: 2 Districts (Umgungundlovu and Pixley ka Seme) Adults 18 and over	Percent of hypertensives diagnosed Percent of hypertensives receiving treatment Percent of hypertensives with controlled blood pressure	Structural quality: Limited availability of testing equipment Perceived prevalence of stockouts Long wait times which reduced care-seeking and patient interest in returning for care	Used a linked survey study design
(Chukwuma et al. 2019)	Mixed-methods (cross-sectional) Household surveys, facility registries, focus group discussions	Tajikistan: 2 regions (Sughd and Khatlon) Adults over 18	Diagnosis Treatment initiation Treatment monitoring Blood pressure control	Structural quality: Insufficient supply of equipment and human resources. Sphygmomanometers are not replaced and calibrated regularly Process quality: Current protocols lack clear guidance for each level of the health system	Also conducted a literature review on the range of clinical and non-clinical interventions that could overcome identified barriers These solutions included mobilizing faith-based organizations, scaling up screening through May Measurement Month and health caravans, leveraging service user interactions with pharmacy care, introducing job aids for providers, and task-shifting to increase provider supply.
(Londoño Agudelo et al. 2019)	Cross-sectional Household survey, health facility records	Cuba: two municipalities (Cardenas and Santiago) Hypertensive patients age 18 and older	Not explicitly defined	Process quality: Type of pharmacological treatment Measured adherence with treatment among those taking drugs using Morisky's Medication Adherence Questionnaire	Used a linked survey study design Receiving drugs and adherence were not associated with higher blood pressure control
(Jayanna et al. 2019)	Mixed-methods (cross-sectional) Household surveys, facility surveys, focus group discussions	India: one urban block in Mysore, Karnataka (population of 990,900) Adults over 18	Not explicitly defined	Structural quality: Facility readiness, human resources, availability of drugs Process quality: Patient adherence to medicines	Used a linked survey study design to interview hypertensives identified in the first phase

Author, year	Study Type/Data source	Study population	Cascade of Care	Quality Measure Reported	Notes
(Heller et al. 2020)	Longitudinal Household survey, health facility records	Uganda and Kenya: (32 communities, population of 157,985) Adults 18 or older	Adults enumerated Adults attended Community Health Campaign Attendees screened Screened and HTN-positive HTN-positive and referred to care Linked to care within 2 years Patients retained after first visit Blood pressure checked at last visit Blood pressure normal at last visit	Process quality: Implementation fidelity of providers (e.g. asked history of HTN, blood pressure checked twice, appropriate linkage to care, appropriate prescription based on examination) Retention in care (follow-up scheduled and attended, blood pressure checked)	Used a linked survey study design

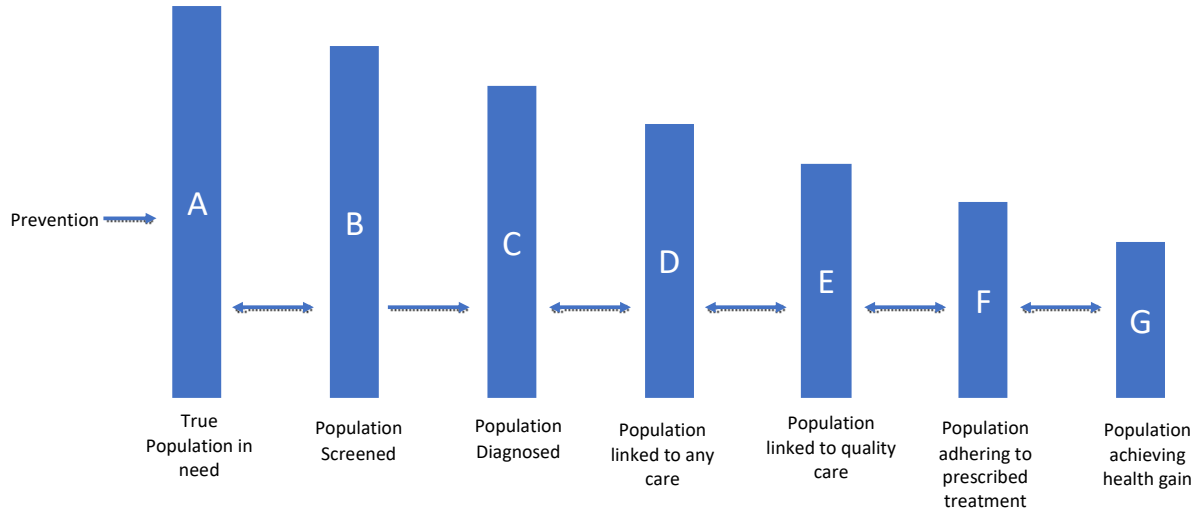
The most common study designs were mixed-methods designs that paired quantitative population-based survey data with qualitative information collected from patients and/or providers. Mixed-methods studies that incorporated qualitative data from patients described structural quality issues such long wait times, lack of drugs, and poor adherence, and outcome quality issues related to patient satisfaction (e.g. poor perceived quality of services) (Wollum et al. 2018; Chukwuma et al. 2019; Galson et al. 2017). Providers described a lack of appropriate equipment, stockouts of medicines, and insufficient time to counsel patients on lifestyle advice (Thorogood et al. 2007; Gabert et al. 2017). Studies that used linked population-based survey study designs with information collected in facilities were able to provide quantitative estimates about these structural quality constraints. Cross-sectional household surveys were also frequently used to understand additional information about hypertension treatment, primarily focusing on availability of health services (including screening and diagnosis), the specific types of

medication taken, adherence to treatment, and patient satisfaction. Five studies did not explicitly define a care cascade and four studies used the traditional hypertension care cascade, however three recently published studies proposed alternative hypertension care cascades. One study separated the treatment step into service initiation and continued treatment (Chukwuma et al. 2019). Another included supply-side considerations, namely contact with the health system (service availability), and the receipt of continuous, high-quality treatment (quality-adjusted treatment) (Macinko, Leventhal, and Lima-Costa 2018). The third study, which linked detailed information from a hypertension screening and management intervention with a household survey, included multiple steps related to screening, referral to care, linkage to care within two years, retainment in care, and then characteristics about the care provided during provider interactions (Heller et al. 2020). Of note, a series of World Bank reports on cascades of care for hypertension which identified supply- and demand-side bottlenecks to achieving hypertension control were identified through grey literature searches, which are presented as a supplementary table (Annex 4)

The structure- and process-related quality features identified in the articles fall into three main categories: facility readiness (including equipment, medicines, human resources), content of care (including adherence to treatment protocols, type of pharmacological treatment prescribed, and health advice given), and patient adherence to treatment (including adherence to medicines, and retention in care). An expanded cascade of hypertension care is proposed that builds on previous standardized steps, incorporating steps to indicate the effectiveness of screening and treatment services provided by the health system (Figure 2.3). Three new steps are proposed in the expanded proposed hypertension care cascade: the percent of hypertensives that have ever had

their blood pressure measured (to indicate frequency of blood pressure screening and early diagnosis), the percent of hypertensives linked to quality care (to indicate the quality of care that follows treatment protocols), and adherence to evidence-based treatment regimens (to indicate the quality of services to increase adherence). Additionally, population-level prevention is acknowledged within the expanded care cascade to include key preventative measures that influence the prevalence of high blood pressure and the likelihood of achieving blood pressure control. On the AXIS scale for rating the quality of observational studies, the 20 studies that informed the expanded hypertension care cascade were of high quality, scoring an average of 15.9 out of 20 (ranging from scores of 9 to 20).

Figure 2.3: Proposed expanded hypertension care cascade



Discussion

Despite major gaps demonstrated between crude and effective coverage, there is no consensus among researchers on what constitutes effective coverage of hypertension management services. The large differences in estimated crude and effective coverage within similar contexts indicates

the massive variability introduced when effective coverage for hypertension management services is calculated using non-standardized methods. The hypertension care cascade is a more commonly used approach to identify bottlenecks in achieving hypertension control, however studies that provide insight into structural and process quality for hypertension management services received by populations are limited. The standardization of this cascade has allowed for many powerful meta-analyses, but gaps remain, as the cascade measures the coverage of hypertension *control*, without accounting for the effect of health system-related *services* that contribute to effective management. Various studies have increasingly tried to fill these gaps by expanding the traditional cascade of hypertension care to include information on process quality such as linkage to services, the content of treatment, and adherence to treatment. Studies have also separated screening for hypertension from the treatment of hypertension, acknowledging that the quality of screening services will influence the number of individuals who are linked to treatment in general. Expanding the hypertension cascade of care framework to incorporate measures of both screening- and treatment-related process quality will help directly identify service bottlenecks across the continuum of hypertension management services. This expanded framework would also bridge the gap between the often-reported cascade of care and the emerging conceptualization of effective coverage by providing an indication of quality-adjusted coverage of hypertension management services.

Previous efforts have characterized steps in care cascades where health benefits can be lost on the pathway to effective coverage, however these have not been applied to hypertension care cascades (Tanahashi 1978; Amouzou et al. 2019; Marsh et al. 2020). The proposed new steps enable the quantification of missed opportunities for hypertension management based on access

to care, and the calculation of quality-adjusted coverage and user-adherence-adjusted coverage of hypertension management services. They also allow for a more comprehensive approach to studying effective coverage of these services beyond health outcomes alone.

While the proposed framework does not yet include standardized metrics for measuring quality of care or patient adherence, some potential measurement methods are proposed based on the results of this review (Table 2.4). Linkage to quality care may refer to the availability of drugs and testing equipment (structural quality), provider fidelity to standard treatment guidelines including prescribing practices and patient adherence (process quality), and/or patient satisfaction (outcome quality other than blood pressure control) among others. These can be measured by including additional questions to population-based surveys or through studies that link findings from household surveys (which provide information on service utilization and health outcomes) and facility-based surveys (which provide information on service quality). Patient adherence can include retention in care over time, adherence to lifestyle modification advice, and/or adherence to medication. These can easily be incorporated as additional questions to household surveys or through more complex methods like pill counts or treatment diaries. Even without standardized measurements of quality of care and patient adherence, it is hoped that the proposed framework can promote the consideration of intermediate outcomes such as fidelity to treatment protocols and regimens when examining population coverage of hypertension services. This consideration will also help to advance the conceptualization of process quality within effective coverage of hypertension management services, contributing to a standardized metric which will help improve health systems performance measurement.

Table 2.4: Proposed expanded hypertension care cascade description

Cascade Step	Description	Proposed Measurement Techniques	Previous Studies that report this step in the care cascade	Notes and Considerations
True Population in Need (A)	Percent of population with blood pressure >140/90 mmHg or previously correctly diagnosed as hypertensive	Cross-sectional and longitudinal population-based surveys with biometric measurements	Part of the existing cascade of care	A high blood pressure reading at one point in time is not sufficient to diagnose hypertension. Cross-sectional studies that classify hypertensives based on one high blood pressure reading may be over-estimating the size of the population in need.
Population Screened (B)	Percent of population with high blood pressure who have had previously had blood pressure measured according to standards	Cross-sectional and longitudinal population-based surveys based on self-report Linked patient observations/facility records to determine how often providers measure patient blood pressure	(Prenissl et al. 2019)	Population beyond those in need (A) should be screened for high blood pressure, however for the cascade framework, it is important to understand how many of those in need of services were previously screened. Individuals may also need to be screened more or less frequently based on other risk factors (e.g. age or comorbidities)
Population Diagnosed (C)	Percent of population with high blood pressure who were previously diagnosed by a health worker	Cross-sectional and longitudinal population-based surveys based on self-report Linked facility records to determine number of hypertensive patients	Part of the existing cascade of care	Often referred to as the population "aware" of their condition. If providers are diagnosing non-hypertensive patients (false positives), the population diagnosed and true population in need (A and C) could be over-estimated
Population linked to any care (D)	Percent of population with high blood pressure who are linked to any treatment	Cross-sectional and longitudinal population-based surveys based on self-report	Part of the existing cascade of care	Previously referred to as the population "treated" or receiving any treatment for hypertension. Discrepancies can arise from differences in definitions of contact coverage (e.g. taking any medication vs interactions with health providers)

Cascade Step	Description	Proposed Measurement Techniques	Previous Studies that report this step in the care cascade	Notes and Considerations
Population receiving hypertension management services according to standards (E)	Percent of population with high blood pressure who are linked to quality treatment	Cross-sectional and longitudinal population-based surveys including the drugs prescribed Linked facility records to determine quality of hypertension care provided	(Macinko, Leventhal, and Lima-Costa 2018; Heller et al. 2020)	This estimate requires some incorporation of a definition of "quality" of hypertension treatment. For standardization purposes, fidelity to national/global treatment guidelines would be the best way to assess service quality.
Population adhering to treatment (F)	Percent of population receiving quality treatment and adhering to treatment as prescribed	Cross-sectional and longitudinal population-based surveys potentially including pill counts or diaries	(Bhandari, Sarma, and Thankappan 2015; Chukwuma et al. 2019)	Adherence to medications and/or lifestyle advice could be considered in this step
Population achieving health gain (G)	Percent of population with controlled blood pressure	Cross-sectional and longitudinal population-based surveys with biometric measurements	Part of the existing cascade of care	Health gain can be defined in multiple ways (e.g. controlled blood pressure levels, improved health, reduced hospitalization)

There are some potential drawbacks to the expanded hypertension cascade of care. One of the major bottlenecks described in the reviewed studies was a lack of facility readiness and structural quality. The percent of population ever screened (step B) is envisioned to be an indicator of facility readiness (to provide blood pressure screening services), however there are shortcomings in this step's ability to fully describe facility readiness. For example, the proposed step does not indicate how recently the individual has been screened for high blood pressure, which has implications for timely diagnosis of hypertension. Further, it does not indicate the quality of the screening services provided (e.g., whether correct cuff size is used, whether blood pressure measured twice) which has a large influence on whether or not a correct diagnosis is made. Other drawbacks include the fact that certain steps are linked to locally relevant factors. Specifically, step E relies on hypertension management services being provided according to standards, which

may vary locally, and step G may rely on a context-specific definition of non-elevated blood pressure (e.g., 140/90 mmHg vs 130/80 mmHg based on locally accepted guidelines). The proposed expanded cascade of care should be further discussed by global and local teams of researchers to reach consensus on how to operationalize this framework in future research.

This study should be considered within its limitations. First, the search strategy excluded studies that did not provide population-representative estimates of hypertension management service coverage. Qualitative studies that examined the extent of provider knowledge relevant to hypertension treatment were therefore excluded (Neupane et al. 2015; Vedanthan et al. 2014). Several representative facility-based studies examined aspects of quality hypertension care, but without linking to a population-level survey, the percent of the population receiving these services, and thus the effective coverage of those services, was unknown (Mbui et al. 2017; Gala et al. 2020). Such linked study designs are common in the maternal and child health literature and should be increasingly used to determine quality-adjusted coverage for non-communicable disease management (Kanyangarara, Munos, and Walker 2017; Marchant et al. 2015; Nguhiu, Barasa, and Chuma 2017; Munos et al. 2018). Second, the final results did not include studies published in a language other than English. At least one study was found in Spanish that included the effective coverage of hypertension but was excluded (Ríos-Blancas et al. 2017). Due to commonalities in authorships and study area with another included article, it is likely that the findings from this article are reflected in the results (Lozano et al. 2006). Third, this study is a review of the quality of hypertension management services, and is not intended to be a comprehensive review of all issues related to measuring effective coverage. While the expanded cascade of care acknowledges the importance of community-level preventive measures, these are not emphasized. Further, with new guidelines suggesting that the ideal threshold blood pressure

is under 130/80 mmHg, the population in need of hypertension series and the hypertensive population with controlled blood pressure will drastically change (Whelton et al. 2018). Studies that have examined the effects of applying these guidelines report increases in hypertension prevalence ranging from 17.6% to 23.8% (Abariga, Al Kibria, and Albrecht 2020; Kibria et al. 2018; Mahdavi et al. 2020). Future studies on effective coverage should consider the impacts of these various guidelines on effective coverage calculations.

Research agendas for infectious diseases that use care cascades to ascertain effective coverage are advancing from simply measuring the cascade steps to conducting quality improvement and implementation research studies to understand how to prevent losses between steps (Subbaraman, Jhaveri, and Nathavitharana 2020; Tun, Go, and Yansaneh 2020; Agins et al. 2019). There are several recently published studies that signal a similar evolution in the hypertension management literature (Limbani et al. 2019; Gimbel et al. 2020; Djasri, Laras, and Utarini 2019). This study contributes to this broader shift in the field by describing measures of non-outcome quality related to hypertension management that can be used to calculate effective coverage. It also proposes an approach to unify previous cascade of care research with the emerging need to account for quality of health services in effective coverage calculations. Within this proposed framework, several additional studies are proposed to deepen understanding of how to achieve effective coverage of hypertension management services (Table 2.5).

Table 2.5: Proposed areas for gap analysis

Gap Analysis and Areas for Further Study	**Description**	**Proposed studies (and examples where applicable)**
Prevention	Community-based prevention measures influence the number of people in need of hypertension services and may also improve blood pressure control (e.g. if high sodium foods become less available)	Effect of salt-reduction interventions on hypertension prevalence (Bernabe-Ortiz et al. 2020)
Screening Gap (A→B)	Those who truly have high blood pressure but either do not get their blood pressure measured because they do not have access to health services or because screening services are not performed when health services are utilized	Cohort studies with routine blood pressure measurements or population-based cross-sectional studies that ask about the last time blood pressure was measured
Diagnosis Gap (B→C)	Those who are screened but are not diagnosed as hypertensive due to faulty equipment, insufficient provider knowledge, or lack of access to health services to receive a formal diagnosis.	Clinical vignettes or standard patients to determine provider knowledge/ ability to diagnose true cases of hypertension
Treatment Initiation Gap (C→D)	Those who are diagnosed as hypertensive but are not linked to any care either because they do not have access to providers or they choose to seek additional care.	Longitudinal studies that follow newly diagnosed hypertensives and determine barriers and facilitators to linking to care (Doulougou et al. 2014)
Quality Treatment Gap (D→E)	Those who are linked to care but the care provided does not follow treatment standards	Clinical vignettes or standard patients to determine provider knowledge/ ability to provide treatment according to standards
Adherence Gap (E→F)	Those who are receiving quality management services but are not adhering to the prescribed treatment for a variety of reasons (e.g. too expensive, medicines unavailable, low health literacy)	Longitudinal studies that track medicine adherence over time and understand
Intervention Efficacy Gap (F→G)	Those who are adhering to prescribed, quality treatment but are still unable to achieve controlled blood pressure or other health gains. Could be due to resistant hypertension or other reasons.	Longitudinal studies that track treatment and adherence over time and also include blood pressure measurements

Conclusion

This study reviewed the evidence on effective coverage for hypertension management, and more broadly, quality within the hypertension care cascade. Although there is no universally

recognized definition of effective coverage or service quality, there are some common approaches to describing barriers on the pathway to effective coverage of hypertension management services. These approaches have been incorporated into an expanded cascade of care framework that considers aspects of structural and process quality. The proposed framework should encourage future studies to consider and incorporate aspects of service quality in population measures of coverage and to improve the understanding of how interventions result in better intermediate outcomes (e.g. expansion of screening services, fidelity to treatment guidelines, and medication adherence). These studies are essential for understanding how to best align interventions and health systems to combat the rising burden of hypertension in low- and middle-income countries. With the rising global burden of non-communicable diseases, this approach of studying effective coverage and quality-adjusted cascades of care can help to advance measurement of health systems performance, ultimately improving the quality of life for people with chronic diseases.

Chapter 3: Barriers on the Pathway to Effective Hypertension Management in Bihar, India

Abstract

Background: Identifying gaps in the continuum of chronic care at the primary care level can inform program design and save lives. This study applies an expanded cascade of care framework to examine supply- and demand-side barriers to achieving effective hypertension management in rural Bihar, India.

Methods: Information from two state-representative household surveys conducted between 2019 and 2020 was used to calculate the population of hypertensive individuals that (i) need services, (ii) have ever had their blood pressure measured, (iii) have received a diagnosis, (iv) are linked to any care, (v) are linked to quality care, (vi) that adhere to prescribed treatment, and (vii) that achieve health gains in rural Bihar. Facility assessments, clinical vignettes, and direct patient observations conducted in 2020 and 2021 provided insights into health systems-related barriers preventing individuals from achieving effective hypertension control.

Results: Care seeking information from 14,386 individuals and blood pressure readings from 45,459 individuals was obtained. Quality of care of 390 providers was assessed. There are an estimated 6.6 million undiagnosed hypertensive individuals in rural Bihar, 2.1 million of which have never had their blood pressure measured before. Providers only measured blood pressure in 30.1% of patients over the age of 30 who visited a clinic. While 95.8% of diagnosed individuals are linked to some care, between 18.8% and 69.4% of those individuals are linked to providers who have demonstrated the knowledge required to diagnose and treat hypertension. From vignettes, 74.2% of providers who treated hypertension were able to correctly diagnose a new case of hypertension. Of these providers who correctly diagnosed hypertension, 59.3% were able

to write an appropriate prescription that would safely reduce the patient's blood pressure, 10.5% advised the patient that they would need to regularly monitor their high blood pressure and 3.4% explained that hypertension is a lifelong condition requiring daily treatment.

Conclusions: The largest barrier to achieving effective hypertension control in rural Bihar is the lack of timely diagnosis, suggesting a need for increased population blood pressure screening services. While the coverage of services for diagnosed individuals is high, the quality of these services is low, preventing hypertensive individuals from achieving optimal health gains.

Introduction

Globally, the epidemiologic transition is well underway, with non-communicable disease (NCD)-related deaths rising from 42.2% to 60.6% of mortality in low- and middle-income countries (LMICs) from 2000 to 2016 (World Health Organization 2018). Local, state, and national health systems are confronted with the challenge of adapting care models to address these chronic, often lifelong conditions, while also maintaining services that have effectively reduced the impact of infectious diseases and maternal and childhood conditions over time. Reorganizing and expanding comprehensive primary health care systems to provide effective management services for NCDs is a key strategy for achieving universal health coverage in LMICs (The Lancet 2018; Hone, Macinko, and Millett 2018; Beaglehole et al. 2008). Understanding barriers to achieving effective coverage of chronic care services at the primary care level can inform future program design and save lives.

Bihar, India's third most populous state, is facing a double burden of persistently high prevalence of infectious diseases and rapidly increasing incidence of chronic illnesses. Hypertension, or high blood pressure[7], is the leading metabolic risk factor for death in the State, and its prevalence is steadily increasing (Indian Council of Medical Research, Public Health Foundation of India, and Institute for Health Metrics and Evaluation 2017; Vital Statistics Division 2012; International Institute for Population Sciences (IIPS) and ICF 2017). Hypertension can be prevented through community- and individual-level interventions and can be managed with cost-effective tools delivered by primary health care systems (Saif-Ur-Rahman et al. 2019; Gaziano, Opie, and Weinstein 2006). However, only 17.3% of adults (age 18-49) with elevated blood pressure in

[7]Hypertension is defined as a systolic blood pressure of 140 mm Hg or more and/or diastolic blood pressure of 90 mm Hg or more and/or taking antihypertensive medication

Bihar are currently taking any medication for blood pressure control (Prenissl et al. 2019). This low level of treatment coverage suggests a lack of access to primary health services in the state.

Bihar's public primary health care system is comprised of community health workers, a limited number of health and wellness centers, sub-centers, primary health centers (PHCs), and community health centers (CHCs). PHCs are supposed to be staffed by formally trained doctors, serve between 20,000 and 30,000 people, and provide curative and preventive services at nominal fees. In Bihar, where 88.7% of people reside in rural areas, PHCs should be a focal point for facility-based service delivery, however in reality, only a minority of people seek care from public health providers (Vital Statistics Division 2012; Office of the Registrar General & Census Commissioner 2011). Instead, people overwhelmingly seek care from local private providers who are either fully qualified doctors (providers with a Bachelor of Medicine, Bachelor of Surgery, or MBBS degree), trained in Indian systems of medicine (providers with a degree in Ayurveda, Yoga and Naturopathy, Unani, Siddha, and Homeopathy, or AYUSH providers), or informally trained (or untrained) providers.

While studies have examined the quality of care provided by India's pluralistic health systems, little is known about how effective public and private primary care providers are in the context of diagnosing and treating non-communicable diseases (Das and Hammer 2005; Das et al. 2020). In Bihar, major information gaps exist relative to hypertension management services, especially in rural areas where informal providers are more prevalent (Rajeev Gupta 2004; Anchala et al. 2014; Rajeev Gupta, Gaur, and S. Ram 2019). This gap is significant in light of the fact that the quality of care is a major driver of provider choice among households with hypertensive

individuals (Kujawski et al. 2018). In order to effectively advocate for increased NCD programming, policymakers must be aware of the gaps existing between the demand for a service and the current supply (and quality[8] of) of that service.

A recent study presented aspects of hypertension care in India among individuals aged 15 to 49 and reported that the crude prevalence of hypertension in Bihar is 12.8% (95% CI 12.0 – 13.7) (Prenissl et al. 2019). Of those individuals, 46.8% (43.3 – 50.4) were previously aware of their high blood pressure status, 17.3% (15.4-19.3) were receiving treatment (currently taking BP-lowering medication), and 12.3% (10.8-14.1) had their hypertension under control (blood pressure <140/90 mm Hg during the time of the survey) (Prenissl et al. 2019). By describing a cascade of hypertension care, this study, like others before it, provides important contributions to describing the hypertension management landscape in India (Devi et al. 2013; Anchala et al. 2014; Rajeev Gupta 2004; R Gupta et al. 2018). However, several key gaps limit this analysis from providing sufficient information to address the burden of hypertension and related diseases in India and other LMICs. Primarily, this analysis does not include individuals over the age of 49, a major shortcoming considering that the odds of hypertension increase significantly with every 5 years over the age of 50 in India (Lloyd-Sherlock et al. 2014). Second, while policymakers can understand the points in the hypertension care cascade where the most patients are lost in Bihar (53.2% have hypertension but are not aware, 29.5% who are aware were not receiving treatment), the current framework does not explore how health systems can close these gaps. Finally, the cascading framework of hypertension care (percent screened, percent aware,

[8] Quality of care is conceptualized as having three parts: structure (the inputs and resources needed to provide care), process (the activities and services actually provided during care) and outcomes (the changes in health realized by a patient) (Donabedian 1966, 1988).

percent treated, and percent controlled) does not consider the effects of adequate input and process quality on health, and therefore presents an incomplete picture of how the Bihari health system is addressing hypertension care. To address the burden of hypertension and related diseases in Bihar and similar LMIC settings, there is an urgent need for research to understand the factors that prevent the achievement of effective hypertension management.

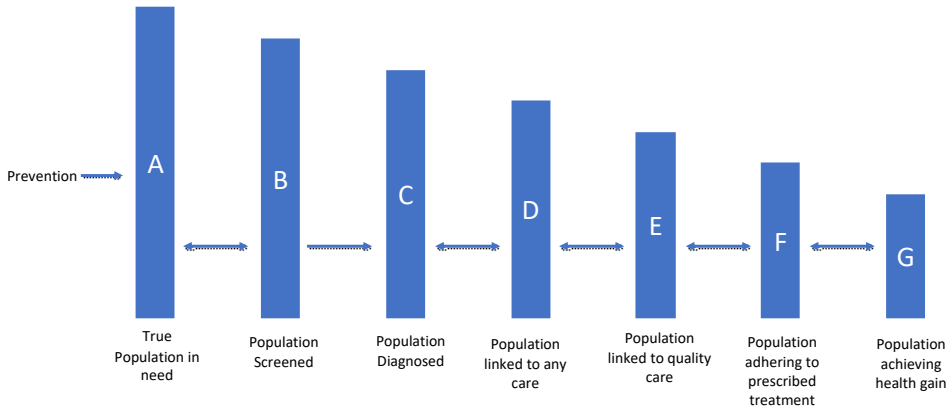
The effective coverage framework is a useful tool for understanding whether populations are receiving the interventions they need at sufficient quality to improve health. Dimensions of need for, use, and quality of hypertension management services can be organized in a stepwise fashion in a cascade of care to indicate levels of care received by populations, progressing from the population in need of services along a cascade of necessary treatment conditions, ultimately ending with the percent of individuals who achieve a specific health gain (Tanahashi 1978; Amouzou et al. 2019). Existing efforts to measure care cascades traditionally focus on the services and health benefits received at the population level, however they do not collect information on the structure- or process-quality related features of services provided by health systems. For health conditions, especially hypertension, there are many factors beyond the health services received by an individual that contribute to a differential risk of disease and subsequent control. These factors, sometimes referred to as social determinants of health, have been documented in several settings and include socioeconomic factors (age, sex, education, and wealth), geography (urban versus rural), health behaviors (smoking, physical activity, diet), and other psychosocial factors (stress, social cohesion, lack of social support) (Basu and Millett 2013; Tapela et al. 2020; Commodore-Mensah et al. 2021; Peltzer and Pengpid 2018). As a result, cascades of care that rely on outcome measures of quality reflect the influence of these

social determinants of health and do not directly reflect health system performance. An expanded cascade of care has been proposed to measure barriers on the pathway to effective coverage of hypertension management interventions based on a scoping review of quality-adjusted services (Chapter 2). Understanding and quantifying supply- and demand-side factors that contribute to drop-off along the cascade of care for hypertension management within the general population can inform future policy for improving hypertension management in primary health care settings in Bihar and other LMIC settings. This study applies the expanded cascade of care as a measurement model to understand aspects of effective coverage of hypertension management services in Bihar, India. By highlighting the health system-related factors that contribute to the largest gaps along the pathway to effective coverage, this analysis will help policymakers to address the most significant bottlenecks to effective blood pressure management, resulting in improved hypertension management in communities.

Methods

This analysis operationalizes the expanded cascade of care as a measurement framework to understand gaps in effective coverage of hypertension management services (Figure 3.1).

Figure 3.1: Expanded hypertension care cascade



The expanded cascade of care was developed based on a scoping review on effective coverage and quality-adjusted coverage of hypertension management services in LMICs (Chapter 2). The cascade's conceptual model is arranged to address the largest reported gaps in hypertension care, namely a lack of structural quality (e.g., lack of preparedness to screen for hypertension and initiate treatment) and a lack of process quality (i.e., treatment that did not follow protocols and inadequate adherence to treatment). The conceptual model also reports on steps that have previously been included in traditional cascades of care, including the percent of hypertensives who are aware of their diagnosis (step C), the percent of hypertensives taking any treatment (step D), and the percent of hypertensives achieving a health gain (step G, when health gain is equated to normal blood pressure levels). The number of individuals at each step will be quantified and health systems-related factors that contribute to gaps between the steps will be examined using the findings from the Assessment of Primary Health Care in Bihar study. The ideal measurements along the steps of the expanded cascade of care, along with the measurements reported in this study, are presented in Table 3.1.

Table 3.1: Measurement model for the expanded hypertension care cascade

Expanded Care Cascade Step	**Operational Definition**	**Ideal Level of measurement**	**Options for Demand Side Measurement**	**Options for Supply Side Measurement**
True population in Need (A)	Percent of population with blood pressure >140/90 mmHg or previously correctly diagnosed as hypertensive	Individual (population-representative)	Population survey with biomarkers: Measure blood pressure of individuals three separate times on the day of survey to indicate high blood pressure (average of second two readings is ≥140/90 mm Hg or the individual is currently taking antihypertensive medication) *	Facility records: List of hypertensive individuals within a primary care facility's catchment area
Population screened (B)	Percent of population with high blood pressure who have had previously had blood pressure measured according to standards	Individual (representative of target population for all screening activities) Facility (readiness to provide screening services)	Population survey: Have you ever had your blood pressure measured by a doctor or other health worker?*	Patient Observations: Observe the percent of patient interactions where blood pressure is measured by provider* Facility assessment: Observe percent of providers with a functioning blood pressure measurement device* Clinical vignettes: Percent of providers who check blood pressure once and twice during patient visit*
Population Diagnosed (C)	Percent of population with high blood pressure who were previously diagnosed by a health worker	Individual Facility (readiness to provide diagnosis services)	Population survey: Have you ever been told by a doctor or other health worker that you currently have hypertension or high blood pressure?*	Clinical Vignettes/Standardized Patient: Measure provider ability to accurately diagnose a hypertensive individual*
Population linked to any care (D)	Percent of population with high blood pressure who are linked to any treatment	Individual	Population survey: In the past 12 months, have you sought care from any provider outside your home to	Patient Observations: Observe the percent of newly diagnosed hypertensives that are linked to care

			manage your hypertension?*	Facility Assessment: What percent of providers have first line antihypertensive medication in stock? What percent of providers treat hypertension? What percent have treated hypertension in the last 6 months? What percent of private providers would refer a newly diagnosed patient to a PHC? *+
Population linked to quality care (E)	Percent of population with high blood pressure who are linked to quality treatment	Individual and provider (linked)	Linked with provider survey: Percent of individuals receiving care from a provider who can provide quality care*	Clinical Vignettes/Standardized Patient: Assess provider ability to prescribe treatment according to standards*
Population adhering to care (F)	Percent of population receiving quality treatment and adhering to treatment as prescribed	Individual Provider (ability to provide appropriate advice)	Population survey: Medication Adherence Questionnaire Medication monitoring, observed therapy, patient-kept diaries How many times have you sought care to manage your hypertension in the last year*+	Clinical Vignettes/Standardized Patient: Measure provider ability to give hypertensive patients advice on adherence*
Population achieving health gain (G)	Percent of population with controlled blood pressure	Individual	Population survey with biomarkers: Measure blood pressure of individuals on the day of survey to indicate controlled blood pressure Population survey: satisfaction with provider, hospitalization due to hypertension*, self-reported health*	NA

*Legend: *Indicates method used in the current study; +Indicates a proxy for the measurement of the respective step on the expanded care cascade*

The methods of the Assessment of Primary Health Care in Bihar study have been explained in detail elsewhere (Chapter 1). Briefly, the study collected both demand- and supply-side data about the primary health care system in rural Bihar using a cross-sectional household survey and a provider assessment respectively. The demand-side data collection consisted of a household survey which employed a three-stage sampling design, with rural PHCs as the primary sampling unit, villages within the PHC catchment area as the secondary sampling unit, and households within the village as the tertiary sampling unit. PHCs were selected from a census of functional PHCs using stratified random sampling proportional to the number of PHCs in Bihar's nine divisions. Villages were sampled by probability proportional to population size from a census of villages within each selected PHC's catchment area, and 30 households were randomly sampled from each selected village using a complete listing of households. All consenting members of selected households were included in the study and administered a standard questionnaire in the local language by trained enumerators. The questionnaire included sections on demographic information, whether the respondent was sick in the last 30 days, and if so, where they sought care and characteristics about their care-seeking experiences. Individuals age 30 and older were asked about care-seeking related to major chronic diseases (hypertension, diabetes, chronic heart disease, asthma, and chronic obstructive pulmonary disease). Data was collected between November 2019 and March 2020. Responses from the household survey informed sampling for the provider assessments.

Local public and private care providers (including MBBS, AYUSH, and informal providers) within 5 km of selected villages that were utilized by respondents from the household survey were found in the community and included in the supply-side provider assessment. The provider

assessment was administered by enumerators with nursing degrees and consisted of three parts: a facility readiness assessment, clinical vignettes, and direct patient observations. The facility readiness assessment was designed to understand the medicines, equipment, human resources, and processes available to providers while giving care. In the clinical vignettes, hypothetical patients were described to providers to assess provider knowledge on how to treat certain conditions (hypertension diagnosis, child diarrhea, child pneumonia, and angina). Providers were prompted to ask questions about the patient's history, list the tests they would conduct on the patient, make a diagnosis, describe the advice they would give the patient, and if necessary write a prescription for the patient. To understand provider practice, nurse enumerators observed patient-provider interactions and recorded provider actions using a standardized form. Enumerators stayed with the provider for up to three hours and observed up to five consultations where the patient presented to the clinic with a new health complaint, collecting information on the same processes observed for the clinical vignettes (i.e., patient history, tests conducted, diagnosis, advice given, and prescription). Data collection for the provider assessment took place between January and March 2020, was halted due to the coronavirus (COVID-19) outbreak, and then completed between February and March 2021. Due to the continuing spread of COVID-19, when data collection resumed in 2021, the patient observation component of the provider assessment was dropped to ensure safety of enumerators and patients.

All tools were pilot tested in rural Bihar to ensure that questions captured intended constructs. Data for the household survey and provider assessment was collected on tablets using SurveySolutions, a free Computer Assisted Personal Interviewing (CAPI) software developed by the World Bank (World Bank, n.d.). Enumerators all had previous experience in data collection

and participated in a week-long training to familiarize themselves with the tool, the CAPI platform, and to resolve any lingering questions. Direct supervision and random response reliability checks were conducted in the field to ensure quality of collected data. All data was passed through logic checks and unusual responses were discussed and resolved between supervisors and enumerators. All cleaning and analysis took place in in Stata (StataCorp 2014). Normalized weights were calculated for each individual in the household survey to account for probability of selection through the study's design and to account for non-response rates. All descriptive statistics for estimates from the household survey incorporated these weights, while estimates from the providers surveys were unweighted due to the lack of a complete sampling frame of private providers. Multiple clinicians who have practiced primary care medicine in India and similar low- and middle-income settings reviewed the prescriptions written by providers in the clinical vignettes, and rated the quality of prescriptions on a scale including (i) inappropriate and harmful, (ii) inappropriate but not harmful, and (iii) appropriate for safely lowering blood pressure using a standardized protocol (Annex 5). To account for the variability in private provider qualifications, supply-side results from the private sector are presented disaggregated by provider training. Two-sample t tests and analysis of variance tests were conducted as appropriate with $\alpha = 0.05$ to determine whether differences between provider groups (private MBBS, private AYUSH, private informal provider, and public providers) were statistically significant. Additional analysis was conducted on the individual and community factors associated with receipt of services (i.e. screening and diagnosis). Since these studies are commonly described in India, this analysis is provided as a supplementary material in Annex 6 (Moser et al. 2014; Rajeev Gupta et al. 2017; Chow and Yusuf 2010; Busingye et al. 2017; Jonas et al. 2010; Kusuma, Gupta, and Pandav 2009; Sathish et al. 2012; Kaur et al. 2012).

Data from the household survey and the provider assessment was linked through a direct matching process to determine the percent of individuals linked to quality care (step E). Hypertensive individuals were matched with the providers from whom they sought care. Individuals were not linked to their providers if they (i) sought care more than 5 kilometers away from their village (because providers were not eligible for the provider assessment), (ii) sought care from medical shops who did also provide some care (because these providers were unable to complete the provider assessment during pretesting), or (iii) sought care from a provider within 5 kilometers of the village but the provider was not able to be located by the study team. Providers were deemed to be of good quality if during the hypertension vignette they both correctly diagnosed the patient as hypertensive, and wrote a prescription that was judged by clinician reviewers to safely lower the patient's blood pressure.

The Assessment of Primary Health Care in Bihar study is approved for human subjects research by the Johns Hopkins University Institutional Review Board (IRB00009563) and by the Sigma Institutional Review Board in India (Doc#'s 1910787106 / 1910789424). All study investigators completed training in human subjects research and declared no conflicts of interest.

Since the Assessment of Primary Health Care in Bihar study did not collect biomarkers on individual blood pressure levels, preliminary results from the fifth National Family Health Survey (NFHS-5) (conducted in 2019) and population data from the most recent national Census (conducted in 2011) were used to estimate the number of people living with hypertension in Bihar (Ministry of Health and Family Welfare, Government of India, and International Institute for Population Sciences 2021; Office of the Registrar General & Census Commissioner 2011).

The NFHS-5, like all previous NFHS surveys, employs a stratified two-stage random sampling design with villages as the primary sampling units and households as secondary sampling units. Responses were representative at the district level and included three measurements of blood pressure for people age 15-49 (women) and 15-54 (men). More information about the sampling procedure and survey can be found online. Estimates collected from the NFHS-5 and the Assessment of Primary Health Care in Bihar study were age-standardized using the rural age-specific population distribution from the 2011 Census (Annex 7).

Results

In total, 39,486 individuals were included in the household survey, including 14,386 individuals who were 30 years or older and answered the chronic disease module and 950 individuals who reported previously being diagnosed as hypertensive (Table 3.2).

Table 3.2: Household survey respondent characteristics

	All respondents (N = 39,486)	**Respondents over 30 (N=14,386)**	**Respondents aware of hypertension diagnosis (N = 950)**
Sex			
Male	18,719 (47.4%)	6,644 (46.1%)	339 (42.0%)
Female	20,767 (52.6%)	7,742 (53.8%)	551 (58.0%)
Missing	0 (0.0%)	0 (0.0%)	0 (0.0%)
Age			
Average (SD)	25.8 (20.2)	48.6 (13.9)	58.0 (13.4)
Religion			
Hindu	35,541 (90.0%)	13,066 (90.8%)	839 (88.3%)
Muslim	3,909 (9.9%)	1,307 (9.1%)	110 (11.6%)
Other (Christian, Buddhist Jain)	26 (0.1%)	8 (0.1%)	0 (0.0%)
Missing	10 (<0.1%)	5 (<0.1%)	1 (<0.1%)
Caste			
Scheduled Caste	10,252 (26.0%)	3,453 (24.0%)	139 (14.7%)
Scheduled Tribe	544 (1.4%)	180 (1.3%)	10 (1.0%)
Other Backwards Caste	24,901 (63.1%)	9,094 (63.2%)	596 (62.8%)
General	3,779 (9.6%)	1.654 (11.5%)	204 (21.5%)
Missing	12 (<0.1%)	12 (<0.1%)	0 (0.0%)
Highest level of Education Achieved			
No schooling	13,115 (33.2%)	8,072 (56.1%)	504 (53.1%%)
Some schooling	18,708 (4749%)	5,034 (35.0%)	349 (36.7%)
Higher secondary schooling or above	4,039 (10.2%)	1,279 (8.9%)	97 (10.2%)
Missing[+]	3,624 (9.2%)	1 (<0.1%)	0
Occupation			
Not employed	30,225 (76.6%)	7,350 (51.1%)	609 (64.1%)
Agriculture	3,111 (7.9%)	2,727 (18.9%)	176 (18.5%)
Labor	3,346 (8.5%)	2,282 (15.9%)	45 (4.7%)
Self-employed	1,920 (4.9%)	1,453 (10.1%)	81 (8.5%)
Service/salaried	875 (2.2%)	572 (4.0%)	39 (4.1%)
Missing	9 (<0.1%)	2 (<0.1%)	0 (0.0%)
Illness in last 30 days			
Yes	15,824 (40.1%)	8,362 (58.1%)	871 (91.7%)
No	23,642 (60.0%)	6,020 (41.9%)	79 (8.3%)
Don't know	11 (<0.1%)	2 (<0.1%)	0 (0.0%)
Missing	9 (<0.1%)	2 (<0.1%)	0 (0.0%)
Hospitalized in last year			
Yes	1,259 (3.2%)	704 (4.9%)	95 (10.0%)
No	33,672 (85.3%)	13,674 (95.1%)	854 (89.9%)
Don't know	12 (<0.1%)	5 (<0.1%)	1 (0.1%)
Missing[+]	4,543 (11.5%)	3 (<0.1%)	0 (0.0%)
Self-Rated Health[*]			
Average (SD)	3.9 (0.8)	3.7 (0.9)	3.3 (0.9)

*Legend: +Question not asked to children under the age of 5; *Self-rated health is assessed on a scale from 1 (very poor) to 5 (excellent)*

The NFHS-5 survey included blood pressure measurements for 45,459 individuals in Bihar. The provider assessment included 390 providers from 70 villages, 368 of whom (94.4%) said they would treat the hypothetical case who presented to the clinic in the vignette. (Table 3.3).

Table 3.3: Provider assessment respondent characteristics

	Private Providers (N = 319)	**Public providers (N = 71)**
Sex of Provider		
Male	311 (97.5%)	62 (87.3%)
Female	7 (2.2%)	9 (12.7%)
Missing	1 (0.3%)	0 (0.0%)
Age of Provider		
Average (SD)	45 (14)	48 (11)
Caste of Provider		
Scheduled Caste	31 (9.7%)	7 (9.9%)
Scheduled Tribe	11 (3.5%)	4 (5.6%)
Other Backwards Caste	165 (51.7%)	31 (43.7%)
General	110 (34.5%)	28 (39.4%)
Other	2 (0.6%)	1 (1.4%)
Place of Residence		
Same Town/Village as clinic	238 (74.6%)	47 (66.2%)
Other town/village	81 (25.4%)	24 (33.8%)
Provider Training		
MBBS	15 (4.7%)	47 (66.2%)
AYUSH	54 (16.9%)	18 (25.4%)
Informal training	250 (78.4%)	0 (0.0%)
Other allopathic medicine	0 (0.0%)	6 (8.5%)
Years worked at facility		
Average (SD)	15 (13)	6 (6)

In the 70 villages where the provider assessment was conducted, 192 individuals self-reported a previous hypertension diagnosis. Of these 192 individuals, 85 were linked to the provider from whom they sought care (Figure 3.2). Twelve individuals were not linked to local providers because the provider was not found. Reasons for not finding these providers included (i) the provider was not able to be located based on information provided by the individual (n=7), (ii) the individual did not remember the name of their provider (n=3), and (iii) the provider was out of town for an extended period during the provider assessment (n=2). In total, our study administered the provider assessment to 83% of the providers from whom care was sought in the household survey. This compares favorably with the provider response rate from a previous study in India with similar study design, which reported a response rate of 41.9% among local providers (Das et al. 2020). Hypertension-related structural and process quality features were determined for public providers and MBBS-trained, AYUSH, and informal providers (Table 3.4). Results are presented along the steps of the expanded hypertension care cascade (Table 3.5).

Figure 3.2: Linking process for determining percent of hypertensives linked to quality care

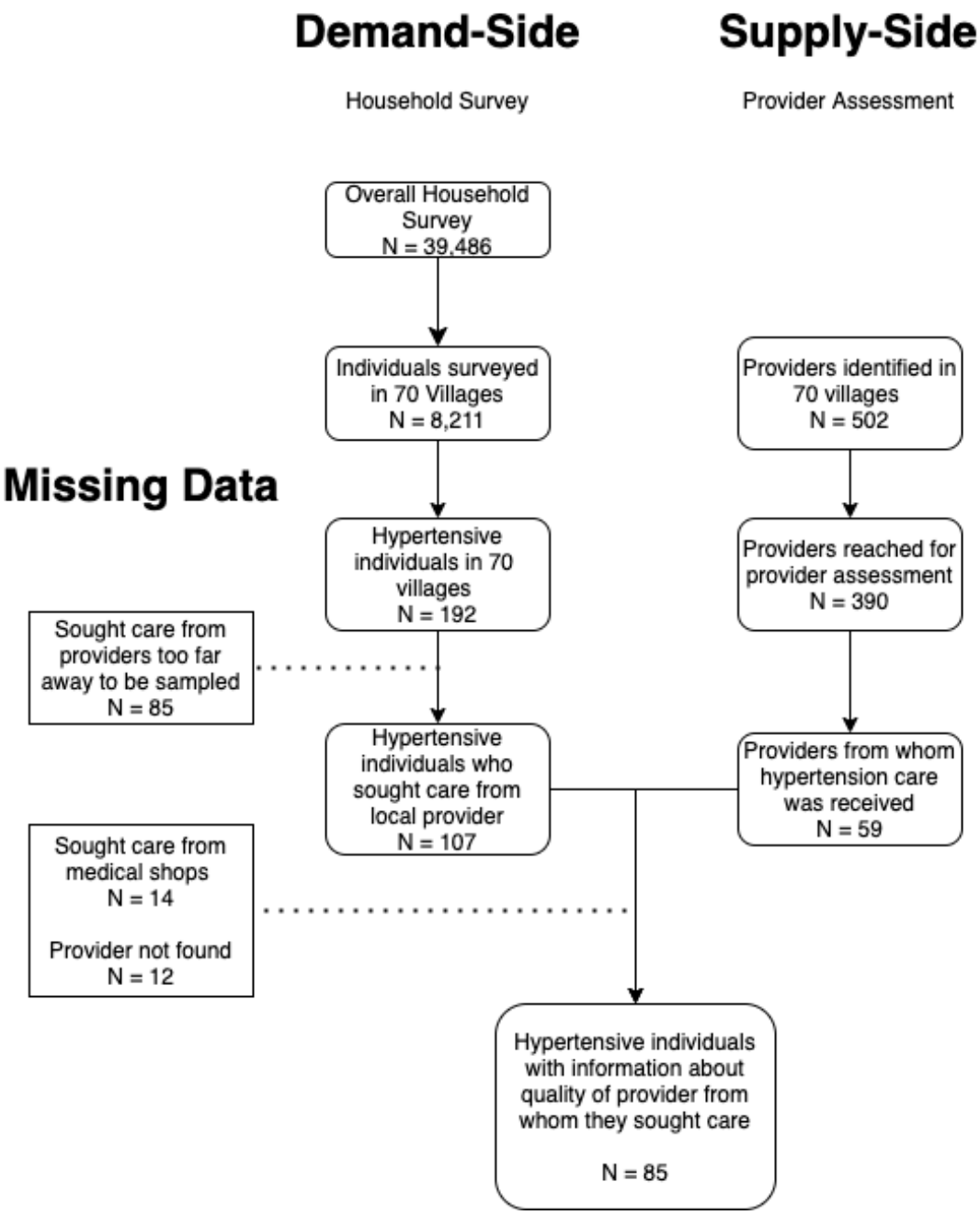


Table 3.4: Supply-side quality characteristics

Domain	Operational Indicator	Private-MBBS (n = 15)	Private-AYUSH (n = 54)	Private-Informal (n = 250)	Public (n = 71)
Structural quality – Screening (B)	Percent of providers with a functioning blood pressure measurement device*	100%	88.7%	88.3%	100%
Process quality – Screening (B)	Percent of patients over age 30 screened for high blood pressure (n = number of patient observations)*	70.0% (n=10)	42.9% (n=21)	31.0% (n=84)	19.7% (n=71)
Process quality – Screening (B/C)	Percent of providers who checked blood pressure once during vignette	100%	92.5%	90%	97.2%
Process quality – Screening (B/C)	Percent of providers who checked blood pressure twice during vignette	21.4%	20.8%	13.5%	23.9%
Process quality – Diagnosis (C)	Percent of providers who are able to correctly diagnose hypertension during vignette *	85.7%	71.7%	70.0%	87.3%
Structural quality – Treatment (D)	Percent of providers who have amlodipine in stock on day of survey*	60%	18.5%	49.4%	82.6%
Structural quality – Treatment (D)	Percent of providers who have hydrochlorothiazide in stock on day of survey*	53.3%	14.8%	21.3%	27.5%
Structural quality – Treatment (D)	Percent of providers who have atenolol in stock on day of survey*	46.7%	14.8%	28.5%	72.5%
Process quality – Linkage to care (D)	Percent of providers who refer a newly diagnosed hypertensive patient to a PHC	14.3%	29.6%	44.0%	NA
Process quality – Quality care (E)	Percent of providers who write a newly diagnosed hypertensive patient an appropriate prescription	66.6%	44.7%	55.3%	77.4%
Process quality – Quality care (E)	Percent of providers who write a newly diagnosed hypertensive patient a harmful prescription	16.6%	13.2%	10.6%	9.7%
Process quality – Quality care (E/F)	Percent of providers who explain to a newly diagnosed patient that hypertension is a lifelong condition requiring daily monitoring and treatment during vignette	0.0%	0.0%	4.3%	9.8%

*Legend: *Indicates a significant difference between provider types at the alpha = .05 level*

Table 3.5: Expanded cascade of hypertension care in Bihar, India

Cascade Steps	Description	Demand Side Measurements	Supply Side Measurements
True Population in Need (A)	Percent of population with blood pressure >140/90 mmHg or previously correctly diagnosed as hypertensive	Hypertension prevalence is 17.0% in adults age 15-49 in rural Bihar (NFHS-5)	NA
Population Screened (B)	Percent of population with high blood pressure who have had previously had blood pressure measured according to standards	77.5% of adults age 30 and older had ever had their blood pressure measured by a health worker	30.1% of adults over the age of 30 presenting to clinics during direct observations had their blood pressure measured by a provider
Population Diagnosed (C)	Percent of population with high blood pressure who were previously diagnosed by a health worker	8.1% of adults ever screened before reported a previous diagnosis of hypertension from a health worker	74.2% of providers were able to correctly diagnose a new case of hypertension
Population linked to any care (D)	Percent of population with high blood pressure who are linked to any treatment	95.8% of adults with a previous hypertension diagnosis visited a health worker to manage hypertension in the last year	94.4% of providers interviewed treat hypertension 82.3% of providers treated a case of hypertension in the past 6 months
Population receiving hypertension management services according to standards (E)	Percent of population with high blood pressure who are linked to quality treatment	4.7% of hypertensive individuals received their usual care from providers who are known to provide quality care	59.3% of providers who accurately diagnosed hypertension wrote prescriptions that were appropriate for lowering blood pressure
Population adhering to prescribed treatment (F)	Percent of population receiving quality treatment and adhering to treatment as prescribed	45.9% of those who sought care saw providers at least 4 times a year	4.8% of providers would advise newly diagnosed patients that hypertension is a lifelong condition requiring daily treatment
Population achieving health gain (G)	Percent of population with controlled blood pressure	9.5% of adults with a previous hypertension diagnosis have ever been hospitalized because of their hypertension (4.6% in the past year)	NA

Legend: Shaded cells indicate measures that are proxies for the respective step on the expanded cascade.

True Population in Need

The NHFS-5 estimates that the state-wide prevalence of hypertension is about 17.0% among individuals over age 15 in rural Bihar. This equates to about 9.5 million individuals in rural Bihar who are somewhere on the hypertension management cascade and in need of health services (Annex 7).

Population Screened

Of the 14,386 individuals in the survey aged 30 or over, 77.5% had ever had their blood pressure measured by a health worker before the survey date (95% CI from 76.3% to 78.6%). For rural Bihar, this equates to an age- and sex-standardized 76.2% of adults who have ever been screened, meaning there are some 13.3 million adults aged 15 or older in Bihar who have never had their blood pressure measured. From the provider assessments, 90.9% of all providers had a functioning blood pressure measurement device at the time of the assessment. Across patient observations, 30.1% of patients over the age of 30 who presented to primary care providers had their blood pressure measured. Patients aged 30 or older presenting to private primary care providers were significantly more likely to have their blood pressure measured than those presenting to public providers (36.5% versus 19.7%). Among private providers, formally trained providers checked adult blood pressure more frequently than informal providers (MBBS providers checked blood pressure in 70.0% of visits, AYUSH providers checked blood pressure in 42.9% of visits, and informal providers checked blood pressure in 31.0% of visits).

Population Diagnosed

In the household survey, 6.3% of all adults over the age of 30 reported ever being diagnosed with hypertension by a health worker. The percent of adults over age 30 reporting a hypertension diagnosis increased to 8.1% among those who had been ever had their blood pressure measured before. Additionally, the prevalence of self-reported hypertension among those over the age of 50 increased by age group from 7.2% of adults age 50-59 to 10.9% of adults age 60-69, rising to 15.2% of those 70 and older. The age-standardized prevalence of hypertension in rural Bihar was estimated at 5.2%. On average, people with a hypertension diagnosis learned about their diagnosis 5.2 years ago, but 20.1% of diagnoses occurred within the last year. Of the providers surveyed who would treat the case, 74.2% were able to correctly diagnose a new case of hypertension in a clinical vignette. While 87.3% of public providers were able to correctly diagnose hypertension, private providers were less likely to correctly diagnose hypertension in a vignette (85.7% of private MBBS providers, 71.7% of private AYUSH providers, and 70.0% of private informal providers). Common incorrect diagnoses included headaches, migraines, or no diagnosis.

Population Linked to Any Care

Of the 950 individuals over age 30 with self-reported hypertension, 95.7% were taking any antihypertensive medication in the last 12 months and 95.8% visited a health worker in the last year to manage their hypertension. The majority availed services from the private sector (46.4% from private doctors and clinics, 18.9% from pharmacies or compounders, 14.5% from private hospitals, and 14.3% from traditional healers). Among the 5.6% of individuals who sought care from the public sector, the majority (58.8%) sought care from district hospitals. Of the 390

providers included in the study, 94.6% report treating hypertension and 82.3% of providers treated a hypertensive patient in the last 6 months. From the clinical vignette, 91.2% of providers who correctly diagnosed a case of hypertension stated they would treat the individual at their clinic. The majority (55.7% of providers) would treat without further referral, but 35.5% of providers would refer the patient to another clinic while starting some treatment. The availability of three first-line antihypertensive therapeutics – a calcium channel blocker (amlodipine), a thiazide diuretic (hydrochlorothiazide), and a beta-blocker (atenolol) – was assessed. Across providers, 40.0% were unable to offer any antihypertensive medication and 12.0% had all three types of medication. The most commonly available antihypertensive therapy was amlodipine (available from 51.5% of providers) and the least commonly available medication was hydrochlorothiazide (available from 23.1% of providers).

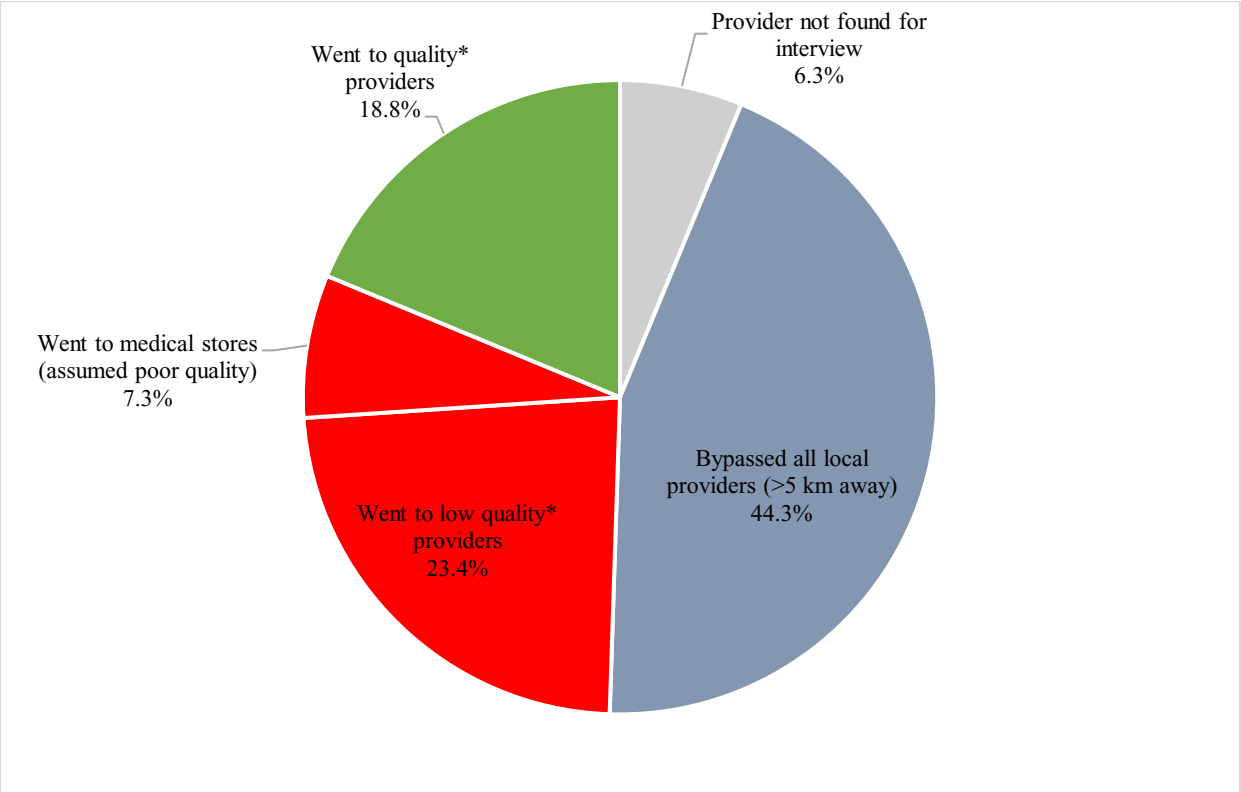
Population Linked to Quality Care

The perceived quality of hypertension management services was an important consideration for individuals in their care-seeking decisions. Of the 933 individuals who sought hypertension management services from the private sector, 62.2% did not seek hypertension treatment from their local PHC due to the low perceived quality of care. This resulted in people traveling an average of 29.2 kilometers (95% confidence interval of 20.9 to 37.5 kilometers) to seek hypertension management services. Across providers, there were gaps in the process quality of hypertension treatment in the clinical vignettes. While 92.1% of all providers measured blood pressure once, only 16.9% of providers measured blood pressure a second time to confirm diagnosis in the vignette. A suite of lifestyle modifications was infrequently recommended as treatment: while 81.6% of all providers recommended reducing salt intake and/or having a

healthy diet, 39.2% advised regular exercise or physical activity, and only 3.0% advised the patient to stop smoking. Among the 325 providers that correctly identified the patient in the vignette as hypertensive, 59.3% of prescriptions were rated as appropriate for safely reducing blood pressure, 15.8% were rated as inappropriate, but not harmful, and 11.0% were rated as harmful to the patient. The safety of 2.9% of prescriptions could not be determined because they contained non-allopathic treatments.

In villages where provider quality was known, of the 192 individuals previously diagnosed as hypertensive, nearly half (44.3%) traveled more than 5 kilometers away to receive care and the quality of these providers was unknown. Nearly a quarter of individuals (23.4%) sought care from local providers who did not demonstrate basic knowledge of hypertension diagnosis and treatment and a further 7.3% sought care from medical stores whose operators were unable to complete the provider assessment due to lack of medical knowledge. Of the 192 hypertensive individuals, 36 (18.8%) were receiving care from providers who were able to accurately diagnose an individual as hypertensive, and who wrote an appropriate prescription to safely lower blood pressure. In total, the quality-adjusted coverage of hypertension management services in rural Bihar is as low as 18.8% and as high as 69.4% if all of the unsampled providers are providing high-quality care (Figure 3.3).

Figure 3.3: Individual hypertension care-seeking in villages where provider quality assessments were conducted (n=192)



*Legend: *A provider is considered to be of sufficient quality if during a clinical vignette simulating care for a hypertensive patient, they (i) correctly diagnose a hypertensive patient, and (ii) write a prescription that is deemed appropriate for safely lowering the patient's blood pressure.*

Population Adhering to Prescribed Treatment

On average, people who sought care outside of the home to manage their hypertension had 4.8 visits to a provider per year. The median monthly amount spent on hypertension management is 250 rupees (US$3.35). From the provider assessment, providers did not generally provide feedback on the chronic nature of hypertension. In clinical vignettes, among providers who gave a new diagnosis of hypertension, 4.8% indicated that they would explain that hypertension is a lifelong condition requiring daily treatment and 14.1% advised that patients would need to regularly monitor their high blood pressure.

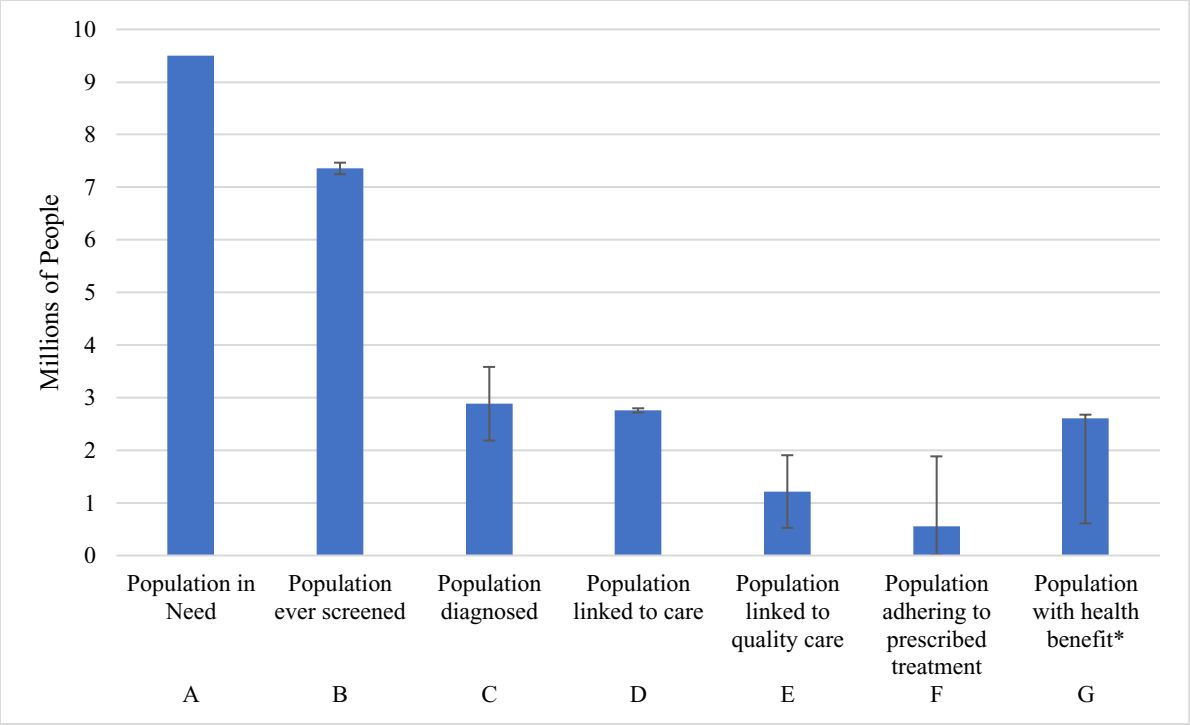
Population Achieving Health Gain

In general, self-rated health was significantly higher among adults age 30 and older who had not been diagnosed with hypertension than adults who had been previously diagnosed as hypertensive. Among respondents who were aware of their high blood pressure, 9.5% had ever been hospitalized due to their hypertension. This includes 4.6% of hypertensive aware patients who were hospitalized for chest pain, cardiovascular problems, or hypertension in the past year.

Expanded Hypertension Care Cascade

When the results are graphed along the expanded hypertension care cascade, the major barriers to achieving effective coverage of hypertension management services are revealed (Figure 3.4). There are some 6.6 million individuals over age 30 in rural Bihar with hypertension who have not been diagnosed (Steps A-C). The majority of these people (4.5 million) have had their blood pressure measured by a health worker at some point, but remain undiagnosed (Steps B-C). This represents the largest gap on Bihar's expanded hypertension care cascade. However, an additional 2.1 million people with hypertension have never had their blood pressure measured by a health worker (Steps A-B). The second major gap is among diagnosed hypertensives who are linked to quality care (Steps E-F). Even though the majority (95.8%) of diagnosed hypertensive individuals are linked to some care, only between 18.8% and 69.4% are linked to providers who provide quality care. This means that between 0.8 and 2.2 million people in rural Bihar are receiving hypertension management services from providers who are unable to provide quality care.

Figure 3.4: Expanded hypertension care cascade for adults over age 30 in rural Bihar and confidence intervals



*Legend: *The point estimate for population with health benefit is hypertensive individuals who had not been hospitalized for their condition. The confidence intervals for population with health benefit are an estimation of those individuals with non-elevated blood pressure.*

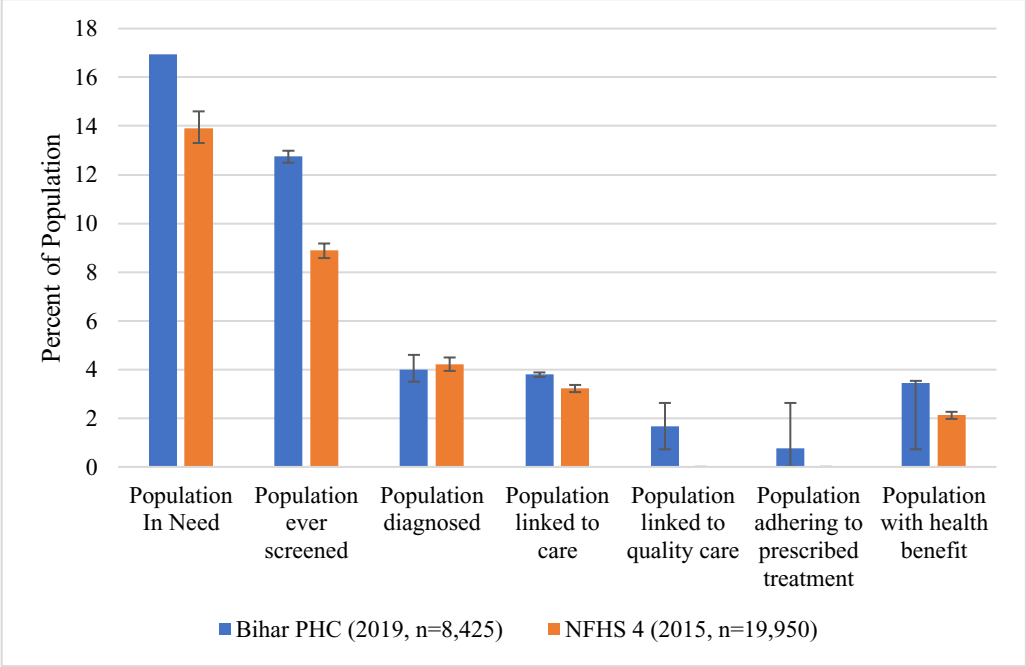
Discussion

This study identifies gaps on the hypertension care cascade and suggests areas for intervention to improve the management of hypertension at the primary care level. The majority of individuals in need of hypertension services have either never been screened for high blood pressure or have been screened at some point but have not been diagnosed by a health worker. When compared with a similar population (rural adults aged 30-54) in the NFHS-4[9], these same steps are consistently where most people are lost along the hypertension care cascade (Figure 3.5). This

[9] NFHS-4 data are used for validation because access to the full NFHS-5 was not granted to the author before the time of publication. These estimates will be updated for future publication.

study contributes the important additional finding that the quality of hypertension management services in rural Bihar is low, potentially preventing millions of people from achieving effective hypertension management. Results from the provider assessments provide insight on areas for health system-wide intervention.

Figure 3.5: Expanded hypertension cascade for adults age 30-54 in rural Bihar across two studies



At least three distinct factors reduce successful hypertension management at the primary care level in Bihar: a lack of service readiness, missed opportunities, and inadequate process quality. Each of these bottlenecks negatively impacts services along several stages of the hypertension cascade. The first gap is caused by insufficient structural quality of providers, who are lacking the supplies needed to diagnose and treat high blood pressure. Over ten percent of private informal and AYUSH primary care providers do not have a functioning blood pressure

measurement device, prohibiting any kind of blood pressure measurement or screening. Even if providers could successfully diagnose an individual with high blood pressure, 39.6% were not able to offer any front-line antihypertensive therapeutics, meaning that a substantial percent of providers are not prepared to initiate treatment upon diagnosis. There are a range of factors that contribute to a lack of available medicines, including logistics and supply chains, procurement preferences, and marketing of medicines. However, it is important that public and informal providers alike should be stocked with functioning blood-pressure measurement devices and a supply of antihypertensive medication to ensure that providers are able to screen patients for high blood pressure, diagnose new cases, and immediately initiate treatment.

Beyond having an appropriate supply of equipment and medications, providers should take advantage of opportunistic screening to improve hypertension management. According to India's national hypertension guidelines, all adults over the age of 18 are supposed to be screened during each interaction with the health system (Ministry of Health and Family Welfare 2016). Despite these recommendations, only 30.1% of adults over age 30 (and 29.7% of adults age 18 and older) who presented to clinics had their blood pressure measured. The guidelines also state that hypertension diagnoses should be made at primary health clinics (Ministry of Health and Family Welfare 2016). Some 47.4% of private providers said that they would not refer a newly diagnosed hypertensive patient to a PHC, therefore missing another opportunity to officially confirm the diagnosis according to national guidelines. Given the fact that the majority of all care is sought from private providers, guidelines should be revised to allow for diagnosis by private facilities.

Screening, diagnosis, and treatment capabilities of providers in rural Bihar are inadequate. Only 16.9% of providers measured blood pressure twice during clinical vignettes, which may result in misclassification of hypertension diagnoses. Even if providers were able to identify a case of hypertension, only 59.3% were able to write an appropriate prescription which could safely lower a patient's blood pressure. Additionally, less than 5% of providers informed newly diagnosed hypertensive patients of the chronic nature of their disease and the actions required to treat it. Among all providers included in the study, only 8.5% measured blood pressure twice, were able to diagnose a new case of hypertension, and wrote an appropriate prescription to lower blood pressure. As previously described in India, the quality of care is an important determinant of facility choice among households with hypertension (Kujawski et al. 2018). The likelihood of receiving high quality hypertension care from a provider in rural Bihar is astonishingly low. In summation, public and private providers alike require training on how to properly measure blood pressure, diagnose hypertension, and provide appropriate advice and pharmaceutical therapy.

Findings from this study are subject to some important limitations. First, the household survey study design was cross-sectional and did not include biometric measurements of blood pressure. This means that neither elevated blood pressure nor blood pressure control could be measured in the household survey, adherence over time could not be tracked, and that all estimates are based on self-reported hypertension diagnosis. One implication is that this study's estimate of step G, the population achieving health gain, is larger than previous steps, which is unusual for care cascades. The NFHS study's large sample size and standard methodology provide reliable and valid estimates of hypertension and can be used as an estimate for the population achieving health gain - future studies should compare hypertension management in the state over time

using these data sources. Additionally, previous studies have demonstrated validity between self-reported and true hypertension status, suggesting that this is an acceptable method for data collection (Najafi et al. 2019). Second, the clinical vignettes were not measurements of what providers did in practice and only four consultations to manage hypertension were directly observed. While studies have demonstrated correlations between provider competence and provider actions, there is typically a gap between the two (Das and Hammer 2014; Leonard and Masatu 2010). However, the knowledge of providers is generally regarded as the upper limit of what a provider can do, so our estimates of provider quality are likely to be conservative in nature. Third, the study design was limited to assessments of providers utilized in local rural markets (within 5 km of a sampled village). While the majority of individuals with hypertension sought care from providers within 5 kilometers of their home (55.6%), over a quarter of individuals (28.2%) traveled more than 20 km to receive treatment, indicating that people may have been traveling to urban centers to seek care where the perceived quality of care was higher. Fourth, due to a lack of standardized metrics and available data, it is difficult to measure the percent of population linked to quality care and the percent of the population adhering to prescribed treatment with confidence. Although this study attempts to describe the percent of individuals linked with quality care (Figure 3.3), the quality of care is unknown for 50.5% of providers utilized. Future studies should endeavor to advance the measurement of quality of care provided by the health system and individual adherence to treatment. The primary strength of this study is that it provides insight into both the supply- and demand-side characteristics of hypertension management in a setting undergoing epidemiological transition.

Our findings for rural Bihar reinforce the conclusions of Prenissl and others that the majority of individuals in India with high blood pressure have either never been screened or are not aware of their condition, (i.e., they have not been diagnosed as hypertensive) (Prenissl et al. 2019). Community-based screening efforts could help to fill this gap, as proactive screening and diagnosis could help to identify hypertension individuals and initiate treatment sooner, however the quality of care in Bihar must also be improved in order to achieve improved health outcomes for more people. This study adds insights about the health systems bottlenecks that are preventing individuals from achieving blood pressure control. Namely, a lack of provider knowledge on how to properly diagnose and treat patients, combined with a lack of provider action to opportunistically screen individuals are contributing to the large number of hypertensives that are either unscreened or undiagnosed. Interestingly, this study suggests that once individuals actually become aware of their high blood pressure status, the vast majority, including those in rural Bihar, are able to access care. However, the quality of care received by individuals in rural Bihar is generally quite low across provider types, which contributes to reduced rates of effective blood pressure management. Future efforts to measure the effective coverage of hypertension management services in LMICs should consider the coverage and quality of a range of services associated with blood pressure control, including screening, diagnosis, and treatment services.

Conclusion

The expanded hypertension care cascade is a useful framework for understanding the state of hypertension management and should be considered for wider use in hypertension and other chronic disease research in LMICs. This framework goes beyond the traditional cascade of care and demonstrates that there are gaps both in the access to screening services and in the ability of

providers to correctly diagnose hypertensive patients. Although improving screening and diagnosis services would have the largest impact on retaining people in the care cascade, this study indicates that the quality of care provided in rural Bihar is low. With the rising burden of non-communicable diseases and hypertension in Bihar, increasing screening practices without first adequately preparing providers and clinics would be irresponsible. Without first improving quality of care, patients newly linked to care are not likely to experience health gains, and may even suffer from adverse effects from the large proportion of providers who are unable to effectively provide hypertension management services.

Chapter 4: An Index for Measuring Effective Coverage of Hypertension Management Services

Abstract

Background: Given the rising prevalence of high blood pressure in low- and middle-income countries, there is an urgent need to assess health system ability to manage hypertension in the population. We describe a comprehensive approach for measuring effective coverage of hypertension management services, and apply the method to rural Bihar, India.

Methods: Information from two state-representative household surveys and a provider assessment (including a facility readiness survey and a clinical vignette) was used to calculate a "hypertension management service coverage index" (HMSCI). The HMSCI combines service coverage measures (percent of adult population screened, percent of hypertensives previously diagnosed, and percent of diagnosed hypertensives currently taking anti-hypertensive drugs) with structural and process quality measures (readiness, examinations, diagnosis, advice, and prescription– all rated on a scale from 0-1) to calculate effective coverage.

Results: Coverage of key hypertension management services in rural Bihar is 69.5% but the effective coverage of these services is 31.3%. Quality of hypertension management services is uniformly low across Bihar. Providers are most proficient in diagnosing hypertension (0.69), but least proficient in providing lifestyle advice (0.41) and correctly examining patients for hypertension (0.42). Public providers (0.77) and privately trained allopathic doctors (0.75) provide significantly higher quality hypertension care than private providers practicing Indian systems of medicine (0.58) and informal providers (0.59).

Conclusions: Effective coverage of hypertension management care is substantially lower than service coverage, limiting hypertension management in rural Bihar. Improvements in the quality

of hypertension care are necessary to address the rising burden of hypertension in rural Bihar and similar contexts and to achieve universal health coverage.

Background

Over a decade has passed since the 2010 global burden of disease study determined that high blood pressure is the leading risk factor for loss of healthy life years globally, yet little has been done to measure and monitor health system capacity to properly manage hypertension at the population level. The scientific community has identified several evidence-based, cost-effective interventions for blood pressure management to prevent cardiovascular disease in low- and middle-income countries (LMICs), including reducing salt intake, increasing physical activity, stopping tobacco use, and prescribing (and adhering to) antihypertensive medication in high risk patients (Murray et al. 2003; Bertram et al. 2018; Kostova et al. 2020; World Health Organization 2010). These interventions can be implemented through primary health care systems and could potentially avert between 1.4 and 1.8 million deaths per year if delivered at scale and following clinical guidelines in LMICs (Lim et al. 2007; Bertram et al. 2018; Kontis et al. 2019). Despite the clear benefits of improving hypertension management, little progress has been made to assess the coverage of high-quality hypertension management services.

The quality of health services provided in low- and middle-income countries is garnering increased attention in the global health literature (Kruk, Larson, and Twum-Danso 2016). This is an essential paradigm shift, as increases in coverage of health services do not result in better population health outcomes unless the services provided are of adequate quality (Boerma et al. 2018; Larson et al. 2017; Kruk et al. 2018). Quality of care is a complex concept that has several components including structure (the physical and organizational features of healthcare settings), process (the delivery of health services), and outcomes (the health benefits received by individuals and populations as a result of care) (Donabedian 1988). Adequate structural quality is

necessary for high quality services, but does not guarantee that services will be delivered according to evidence-based standards. Measuring quality of care solely based on health outcomes has the benefit of being directly linked to population health, but does not indicate how to improve the process of delivering care. Additionally, health outcomes are influenced by social determinants of health, which exist beyond the health system and may reduce the direct link between services provided and health status. Quality of care has been incorporated into measurement of service coverage through the effective coverage metric.

Effective coverage measures the fraction of potential health gain actually delivered through the health system to populations in need, and is estimated by multiplying the utilization (0 if not utilized and 1 if utilized) and quality of a service (scaled between 0, lowest quality, and 1, optimal quality), conditional on the need for the service (Shengelia et al. 2005). Since effective coverage can be calculated at the individual level, averaged across interventions, and aggregated to sub-national and other various units of analysis, it has been adopted as a metric for monitoring overall health systems performance, including progress towards Universal Health Coverage (UHC) (Ng et al. 2014). Key studies have calculated effective coverage scores within specific services (e.g. obstetric care), for multiple services at the national level (e.g. in Mexico), and across multiple services and countries (Larson et al. 2017; Lozano et al. 2006; Hannah H Leslie et al. 2017). Despite the growing interest in measuring effective coverage, little has been done to apply the concept specifically to hypertension management services.

Basic services to manage hypertension can be provided at low cost at the primary care level, either at facilities or in communities. In Bihar's pluralistic health system, a number of actors

provide primary health care services, including public providers (who work in primary health centers or community health centers), private allopathic providers (clinicians with Bachelor of Medicine, Bachelor of Surgery degrees, or MBBS providers), private alternative medicine providers (practitioners with degrees in Ayurveda, Yoga and Naturopathy, Unani, Siddha and Homeopathy, or AYUSH providers), and private informally trained providers (called IPs). A range of services are involved in providing effective hypertension care. First, at-risk populations must have their blood pressure measured regularly and accurately. Next, a health worker must be able to correctly diagnose an individual as hypertensive and communicate the implications of a diagnosis to a patient. Third, the health worker must prescribe an appropriate regimen of appropriate lifestyle changes and pharmaceutical therapies, adapting the regimen as necessary based on the patient's response to treatment until blood pressure is lowered to a non-elevated level.[10] Finally, the patient must adhere to the recommended regimen and maintain a healthy level of blood pressure. Previous efforts to measure effective coverage for blood pressure management tend to either focus on select parts of these services (e.g. screening) or solely on outcome measures of normal blood pressure, however there is no consensus on a single metric (Charoendee et al. 2018; Yang Zhao et al. 2020). A scoping review found that effective coverage for hypertension management has been defined in at least eight different ways (Chapter 2). In part because there is no single indicator for tracking effective coverage of hypertension management services, hypertension has not been incorporated into overall indices for measuring health systems performance and progress towards UHC (Table 4.1). As a result, none of the indicators used to track UHC are currently measuring health system ability to provide effective

[10] The definition of elevated blood pressure varies based on the guidelines used. In accordance with national Indian guidelines, elevated blood pressure is defined as systolic blood pressure greater than 140 mm Hg or diastolic blood pressure greater than 90 mm Hg (Shah and Association of Physicians of India 2019)

services to manage hypertension. Whereas immunization, antenatal care, and HIV/AIDS services each regularly appear in these indices, hypertension management is neglected. Given the substantial global burden of hypertension, this is a major shortcoming in the UHC monitoring framework that requires urgent attention.

Table 4.1: Universal health coverage monitoring indices and consideration of hypertension management

Index Name and Publication	**Representation of Hypertension**	**Comments**
World Bank service coverage index (2020) (Boerma, AbouZahr, et al. 2014; Wagstaff et al. 2015; Boerma, Eozenou, et al. 2014)	None	"We excluded… hypertension treatment and diabetes treatment mostly on the grounds that few household surveys collect the necessary data."
WHO UHC service coverage index (2019) (World Health Organization and World Bank 2019)	Age-standardized prevalence of non-raised blood pressure (systolic blood pressure < 140 mm Hg and diastolic blood pressure < 90 mm Hg) among adults aged 18 years and older (proxy for health promotion and medical services)	Alternative indicator: "Measure of treatment coverage among people with hypertension" "Measuring effective treatment coverage is also a priority, particularly since linked individual-level data on disease prevalence, treatment status, and clinical control are increasingly available for people with hypertension and diabetes"
GBD 2019 - UHC effective coverage index (Lozano and GBD 2019 Universal Health Coverage Collaborators 2020)	None	"Due to limited data quantity or quality (or both), we could not include several original candidates for effective coverage indicators including some expressly recommended by the GPW13 ERG, including effective management of hypertension and diabetes"
GBD 2017 – UHC service coverage index for SDGs (Lozano et al. 2018)	None	Not acknowledged
Health service coverage index (Leegwater, Wong, and Avila 2015)	None	Not acknowledged

India, like many LMICs, is suffering from a steadily rising burden of hypertension (Devi et al. 2013). In 2015, the national prevalence of hypertension was 18.1% among those under the age of 50, with substantial gaps in screening, awareness, treatment, and hypertension control (Prenissl et al. 2019). Although the country has made a commitment to increasing access to primary care services to treat non-communicable diseases (NCDs), little is known about the quality of services actually provided by public and private providers to manage high blood pressure in India. Studies have demonstrated a wide variation in the quality of primary care more generally across the nation, with formally trained providers in impoverished states like Bihar performing significantly worse than informal providers in other states, but these studies did not focus on hypertension management or other NCDs (Das et al. 2020). Furthermore, the quality of hypertension management services, specifically process quality, seems to drive patient choice in provider for hypertension management in India (Kujawski et al. 2018). Gaps along the pathway to effective coverage of hypertension management services have been identified in rural Bihar, India, but effective coverage of the services associated with hypertension management has not been adequately measured in the state or the country (Chapter 3). Summary measures of effective coverage that can be calculated nationally, sub-nationally, and across various sociodemographic characteristics can promote equitable action and strengthen accountability for improving provision of services. There is currently no such summary measure for monitoring the effective coverage of hypertension management services. This study describes a comprehensive approach for measuring effective coverage of hypertension management services, and illustrates the application of this approach to estimate effective coverage of hypertension management services in rural Bihar, India.

Methods

Study Site

Bihar is amongst the poorest states in India with a population of about 100 million, making it more populous than all but 14 countries in the world. The state is located in northeast India, covers a total area of about 95,000 square kilometers (about the same size as Portugal), and is geographically dominated by the Ganges River and its floodplains. Despite its immense population in a relatively small geographic area, 88.7% of the population is considered to live in rural areas (Office of the Registrar General & Census Commissioner 2011). Bihar is comprised of 38 districts split into 9 divisions. Although the population is relatively young, Bihar is currently experiencing epidemiologic transition and is suffering from a double burden of acute and chronic conditions (42.6% of disease burden is due to communicable disease, 47.6% is due to noncommunicable disease) (Indian Council of Medical Research, Public Health Foundation of India, and Institute for Health Metrics and Evaluation 2017). As in many other states in India, Bihar has a pluralistic health system in which both allopathic and homeopathic systems of medicine are practiced.

Data Sources

A hypertension management services coverage index (HMSCI) is proposed to estimate effective coverage of hypertension services. Calculation of the HMSCI is primarily based on a linked household survey and provider assessment in rural Bihar, from the Assessment of Primary Health Care in Bihar (APHCB) study. The sample size motivations and details of this study have been previously described (Chapter 1). Briefly, the household survey was a multi-stage cluster sampling survey designed to provide division-representative estimates of individual care-seeking behaviors in rural Bihar. The survey did not include biometric data, however adults aged 30 and

older indicated whether they had ever had their blood pressure measured by a health worker, whether they had been previously diagnosed with hypertension by a health worker, and if so, characteristics of the care they receive to manage their hypertension. All members of sampled households indicated the facilities/providers from which they sought any health care services, including those to manage hypertension, in the last 30 days. Local private providers (those within 5 km of the sampled village) identified in the household survey and providers at the nearest Primary Health Clinic (PHC) comprised the sampling frame for the provider assessment.

In one fifth of sampled villages from the household survey, provider assessments were administered to all identified sources of health care services, including public providers, private providers with formal training, practitioners of Indian systems of medicine, and informally trained providers. The provider assessment included a facility readiness assessment, used to determine structural quality of the caregiving setting, and clinical vignettes to indicate a measure of process quality. In a clinical vignette, a provider is presented with a hypothetical case and indicates the process of history-taking questions, examinations, diagnosis, and treatment she would perform for that patient. Although some researchers have noted a gap between what clinicians say they will do in vignettes and what they actually do in practice, an emerging body of evidence suggests that provider knowledge, as assessed by clinical vignettes, is a valid measure of the process of care provided in actual clinical practice (Leonard and Masatu 2005; Peabody et al. 2000; Dresselhaus et al. 2004). The vignette methodology has been used extensively to assess an upper bound of a provider's ability to provide quality care in India and other LMICs (Das et al. 2020; Das and Hammer 2014, 2005, 2007). The vignette used to assess provider quality of care for hypertension management was based on a hypothetical 55-year-old

female patient who presents to a clinic with a headache and a previous high blood pressure reading (Annex 8). The vignette was designed in consultation with doctors and pilot tested with local primary care providers in Bihar for psychometric validation. Interviewers were trained on how to provide standard responses throughout the vignette administration.

This study also employs data from Bihar's portion of the 2014-2015 National Family Health Survey (NFHS-4). The NFHS-4 is a national survey conducted on a sample of women aged 15-49 and men aged 15-54 that is representative at the district level (International Institute for Population Sciences (IIPS) and ICF 2017). NFHS-4 includes biometric information, including blood pressure measurements, from a sample of women and men.

Index Development

The HMSCI was developed based on a conceptual model of how hypertension management services contribute to improved health among individuals with raised blood pressure (Figure 1.3). This conceptual model demonstrates that the effect of the use of hypertension management services on health gains is influenced by the quality of these services, necessitating a representation of quality-adjusted coverage. The HMSCI also relies on the framework used to calculate effective coverage, where the coverage of services is adjusted by service quality (Shengelia et al. 2005). The index was constructed following an internationally recognized methodology for constructing a composite indicator (Nardo et al. 2005; Saltelli 2007) (Table 4.2). The HMSCI was calculated for Bihar, India, and consists of a composite measure of hypertension management service coverage, adjusted by a composite quality of service score.

Table 4.2: Steps for the construction of the hypertension management services coverage index

Step	Description	Application to study
Theoretical framework	A theoretical framework should be developed to provide the basis for the selection and combination of single indicators into a meaningful composite indicator under a fitness-for-purpose principle.	Two theoretical frameworks are used- the expanded care cascade for hypertension management for the concepts related to hypertension management and the effective coverage framework for constructing a composite indicator of effective coverage
Data selection	Indicators should be selected on the basis of their analytical soundness, measurability, country coverage, relevance to the phenomenon being measured and relationship to each other. The use of proxy variables should be considered when data are scarce.	Indicators for service coverage were selected based on their ability to be measured at the population level. Indicators for quality were selected based on their relevance as assessed by clinical experts and on their ability to be standardized across settings.
Multivariate analysis	An exploratory analysis should investigate the overall structure of the indicators, assess the suitability of the data set and explain the methodological choices, e.g., weighting, aggregation.	Exploratory analyses found that certain individual characteristics were associated with likelihood of blood pressure measurement and diagnosis – some shortcomings in the dataset are addressed
Imputation of missing data	Consideration should be given to different approaches for imputing missing values. Extreme values should be examined as they can become unintended benchmarks.	Missing blood pressure measurements were addressed by referencing a survey (NFHS-4) that took blood pressure measurements.
Normalization	Indicators should be normalized to render them comparable.	All coverage indicators are normalized on a scale of 0-100% coverage of quality services
Weighting and aggregation	Indicators should be aggregated and weighted according to the underlying theoretical framework.	Individual coverage indicators were calculated using weights to account for survey design. Coverage of services was equally weighted using the geometric average, and the final coverage index was multiplied by quality (rather than averaged) following the effective coverage framework
Robustness and sensitivity	Analysis should be undertaken to assess the robustness of the composite indicator in terms of e.g., the mechanism for including or excluding single indicators, the normalization scheme, the imputation of missing data and the choice of weights.	Multiple measures of coverage (including contact with any provider in the last year vs taking any antihypertensive medication) and quality were assessed to determine stability of the effective coverage index.
Links to other variables	Attempts should be made to correlate the composite indicator with other published indicators as well as to identify linkages through regressions.	In an assessment of validity, the HMSCI was compared with other potential measures of effective coverage
Visualization	Composite indicators can be visualized or presented in a number of different ways, which can influence their interpretation.	The HMSCI was mapped to demonstrate variation in service coverage and effective coverage across the state
Back to the real data	Composite indicators should be transparent and be able to be decomposed into their underlying indicators or values.	The methods section describes in detail the calculation of the individual coverage indicators and the effective coverage

Index Calculation

The HMSCI is composed of coverage indicators for three services related to hypertension management and is adjusted by a composite quality score (incorporating dimensions of structural and process quality) for providers. The three coverage indicators are: (i) screening of the general population, (ii) hypertension diagnosis, and (iii) linkage to care (Table 4.3). These three indicators are selected based on the conceptual framework and represent the coverage of preventive services in the general population, the coverage of diagnostic services in the hypertensive population (both measures of secondary prevention), and the coverage of tertiary prevention services (hypertension treatment). While an indicator for the coverage of primary preventive services is missing, these indicators represent a more complete understanding of the services provided to an individual throughout the life-course, an essential component of measuring UHC (Lozano and GBD 2019 Universal Health Coverage Collaborators 2020; Fullman and Lozano 2020). Appropriate survey weights were utilized to account for the design of each of the surveys and calculate division-wide estimates of the percent of individuals in need of each service who receives it. Overall coverage of the three services is calculated using the geometric average of the three individual service coverage scores. The geometric mean is used because it takes account of positive synergies and negative externalities that are not accounted for through the use of the arithmetic mean (Biggeri et al. 2019).

Table 4.3: Calculation of coverage components of the hypertension management services coverage index

Service	Numerator (use)	Denominator (need)	Data source
General population screening	Number of adults over 30 who have ever had their blood pressure measured	Number of adults over 30	APHCB household survey
Awareness of hypertension diagnosis	Percent of adults over 30 who self-report being previously diagnosed as hypertensive	Percent of adults over 30 who are considered to have high blood pressure* on the day of survey	Numerator - APHCB household survey Denominator – NFHS-4
Linkage to care	Number of adults over 30 who have taken a medication to lower blood pressure in the last 12 months	Number of adults over 30 who report being previously diagnosed as hypertensive	APHCB household survey

*Legend: *An individual is considered to have high blood pressure if (i) the average of the second two systolic blood pressure measurements was ≥140, (ii) the average of the second two diastolic blood pressure measurements was ≥ 90, or (iii) if the individual was taking a prescribed medicine to lower their blood pressure*

The quality score for individual providers is calculated using items from the facility assessment and from the examination, diagnosis, advice, and treatment sections of the hypertension vignette for a total of five quality domains (Table 4.4). Previous studies analyzing results from clinical vignettes have combined scores on individual items into an index using weights generated through item-response theory, weights based on relative importance of items based on guidance from clinicians, and through simple averages of included items (Das and Hammer 2005; Peabody et al. 2000; Leonard and Masatu 2005). To enhance transparency, this study utilizes the simple average calculation method, though four alternative index aggregations were calculated and compared (Annex 9). Items in the final index are included based on three clinicians'

assessments[11] of the most important aspects of hypertension management. Across a quality domain, the number of goods available (in the facility assessment) or actions taken (in the vignette) are summed and then divided by the total number of relevant items in each domain. To assess the appropriateness of treatment, a standard protocol was employed by two clinicians to judge whether prescriptions written by sampled providers would likely result in a healthy reduction in blood pressure over time using a standard protocol (Annex 5). For each provider, the average domain-wise score was summed and then divided by 5 to obtain a final quality score, which is bounded between 0 (worst quality) and 1 (highest quality). The quality score is averaged across all providers within a geographic district to receive an aggregate quality adjustment score in a region. Additionally, the quality of hypertension management services is calculated and presented by provider type.

[11] The clinicians involved in the assessment included a primary care physician currently practicing in rural Bihar, a primary care physician trained in an LMIC setting in Southeast Asia, and an emergency room physician from Johns Hopkins. The clinicians weighted the relevant "importance" of various items within the hypertension vignette and the most "important" items were kept in the quality index.

Table 4.4: Inputs for the HMSCI quality score

Type of Quality	**Domain**	**Item(s)**				
Structure (facility assessment)	Service Readiness	Functional blood pressure measuring device	Atenolol available	Amlodipine available	Ramipril available	Telmisartan available
Process (vignette)	Examinations	Checks BP once	Checks BP a second time	Checks pulse		
	Diagnosis	Accurate diagnosis of hypertension				
	Advice	Provider suggests diet improvement (reduced salt intake)	Provider suggests increased physical activity	Provider suggests patient to monitor blood pressure		
	Prescription	Prescription is deemed appropriate				

Mirroring the calculation of effective coverage first described by Shengelia and colleagues, the HMSCI is calculated by multiplying the service coverage index by the provider quality index, or in other words, the product of utilization of services (conditional on need) and quality (Shengelia et al. 2005). To demonstrate the ability to aggregate the HMSCI at various geographic units, effective coverage of hypertension management services is calculated at the division- and state-levels.

Data Analysis

All analysis was done in Stata SE version 14.1 (College Station, TX). Wald tests and Bartlett's test of equal variance were calculated to determine whether there were significant differences

across divisions in input indicators and the final index. For providers that responded they would not give treatment to a patient after making a diagnosis, no further information was collected about advice given or prescriptions, and the provider received a "0" for quality on that section. With the exception of one provider who opted out of the facility assessment, there was no missing data.

Results

The APHCB study included 14,386 individuals aged 30 years or older and 950 individuals who were previously diagnosed as hypertensive in rural Bihar. The NFHS-4 study included biometric information on 51,684 individuals in Bihar, including 44,480 who lived in rural areas. The provider survey collected data on 390 providers, including 71 public providers, 15 MBBS-trained private providers, 54 AYUSH private providers, and 250 informal providers. Among adults in rural Bihar, the overall coverage of hypertension management services is relatively high (Table 4.5). The coverage of blood pressure measurement services among adults over the age of 30 was 77.47% state-wide, varied significantly ($p<0.01$) across the divisions, and ranged between 70.09% of the population (Bhagalpur division) and 83.03% of the population (Purnia). Awareness of hypertension diagnosis varied significantly across the divisions ($p<0.01$). Relatedly, the percent of expected hypertensives aware of their diagnosis was 45.24% across the state and showed the greatest amount of variation of any hypertension management service, ranging from 32.06% (Bhagalpur division) to 93.53% (Patna division). Finally, the vast majority of individuals (95.78% state-wide) who were aware of their hypertension diagnosis were taking antihypertensive medication, ranging from 91.26% (Patna division) to 100% of sampled individuals in the Purnia division, and significant variance was observed between the divisions

($p<0.01$). In all, the service coverage index ranged from 59.54% (Bhagalpur division) to 86.52% (Patna division) with a state-wide average of 69.5%.

Table 4.5: HMSCI calculation in rural Bihar by division

Division **(A)**	**Percent Screened** **(B)**	**Percent of Expected Diagnosed** **(C)**	**Percent of diagnosed taking anti-hypertensive drugs** **(D)**	**Service Coverage Index** **(E = (B*C*D) $^{1/3}$)**	**Quality Score** **(F)**	**Effective Coverage (HMSCI)** **(G = E * F)**
Bhagalpur	70.09%	32.06%	93.93%	59.54%	0.38	22.63%
Darbhanga	78.06%	51.16%	98.24%	73.20%	0.54	39.53%
Kosi	75.97%	33.20%	96.70%	62.48%	0.56	34.99%
Magadh	73.16%	54.75%	96.23%	72.78%	0.46	33.48%
Munger	77.92%	32.14%	94.00%	61.74%	0.29	17.90%
Patna	75.87%	93.53%	91.26%	86.52%	0.40	34.61%
Purnia	83.03%	29.98%	100.00%	62.90%	0.52	32.71%
Saran	80.54%	38.74%	95.66%	66.83%	0.41	27.40%
Tirhut	77.76%	50.58%	97.11%	72.55%	0.46	33.37%
Bihar	77.47%	45.24%	95.78%	69.50%	0.45	31.28%

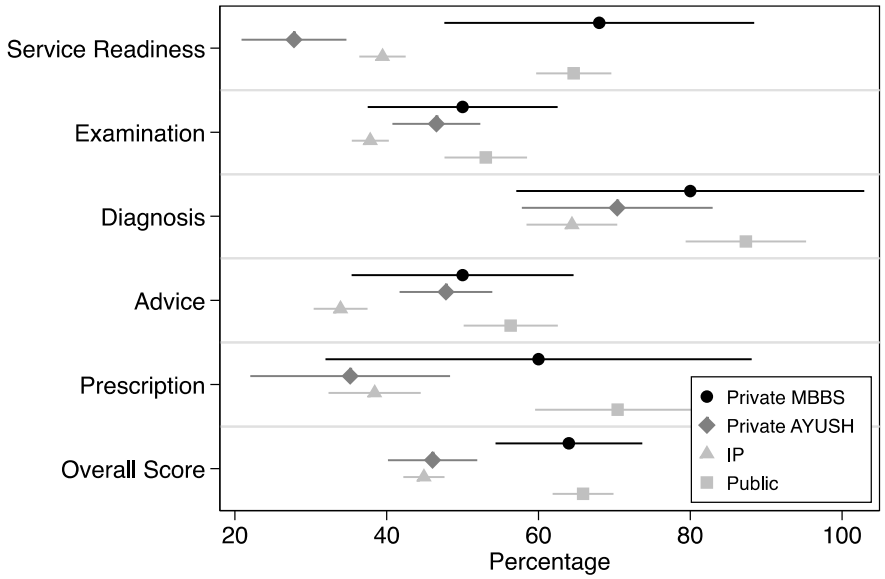
The simplified quality score for management of hypertension (including structural quality) yielded the highest average quality score, and the ranking of division by quality was relatively stable across calculation methods (Annex 9). The overall quality of hypertension management services did not vary significantly across the divisions ($p=0.41$) (Table 4.6). Providers were weakest in their ability to give lifestyle advice about hypertension: across divisions, 81.60% of providers gave advice to keep a healthy diet, however less than half (39.17%) of providers advised patients to increase exercise, and only 13.06% of providers advised the patient that they would need to monitor their blood pressure over time. Across quality categories, providers were best at making a diagnosis, with 69.47% of all sampled providers able to correctly make a hypertension diagnosis. Common misdiagnoses included headaches, migraines, or no diagnosis.

Table 4.6: Quality of hypertension management services in rural Bihar

	Service Readiness	**Examination**	**Diagnosis**	**Advice**	**Prescription**	**Quality Score**
Bhagalpur	0.49	0.42	0.44	0.39	0.38	**0.38**
Darbhanga	0.47	0.44	0.70	0.45	0.54	**0.54**
Kosi	0.48	0.39	0.60	0.42	0.56	**0.56**
Magadh	0.47	0.38	0.75	0.39	0.46	**0.46**
Munger	0.38	0.48	0.62	0.36	0.29	**0.29**
Patna	0.44	0.42	0.69	0.43	0.40	**0.40**
Purnia	0.47	0.40	0.81	0.32	0.52	**0.52**
Saran	0.34	0.43	0.66	0.43	0.41	**0.41**
Tirhut	0.43	0.45	0.69	0.41	0.46	**0.46**
Bihar	0.44	0.42	0.69	0.41	0.45	**0.45**

The quality of hypertension management services was assessed by provider type in rural Bihar (Figure 4.1). Public providers performed significantly better than IPs in all 5 quality categories. Additionally, public providers performed significantly better than AYUSH providers in terms of service readiness, diagnosis, prescription, and overall quality. IPs had significantly better service readiness than AYUSH providers, but both were significantly worse than private MBBS and public providers. Despite the small sample of private MBBS doctors, both private MBBS doctors and public doctors demonstrated significantly better knowledge of hypertension management than IPs and AYUSH providers.

Figure 4.1: Quality of hypertension management services in rural Bihar by provider type



Note: (1) IP is Informal provider, MBBS is a provider with an MBBS degree, AYUSH is provider with a degree. in Indian systems of medicine or homeopathy.
(2) Figures represent point estiamtes and 95% confidence intervals.

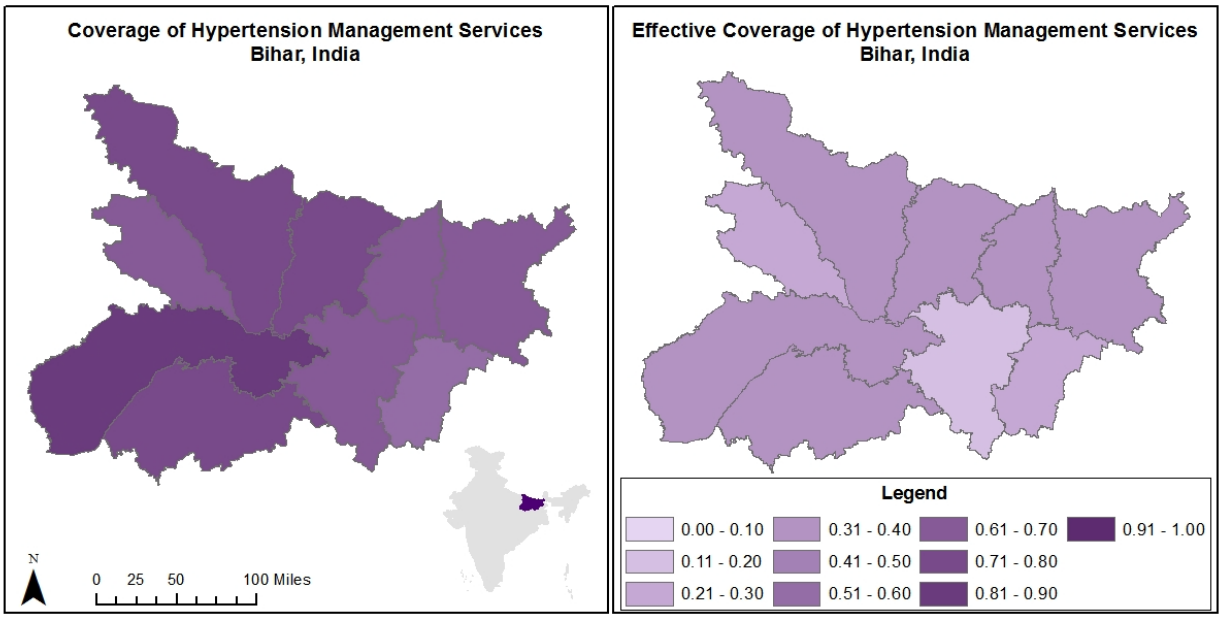
When accounting for quality, the coverage of hypertension management services drops from 69.5% in crude coverage to 31.28% in effective coverage statewide. Effective coverage of hypertension management services ranges from 17.90% in Munger to 39.53% in Darbhanga.

Discussion

To our knowledge, this study is the first attempt to combine indicators of structure and process quality into a measure of effective coverage for non-communicable disease management services. While services such as contact coverage for blood pressure measurement in adults and linkage to care among hypertensives are generally high in rural Bihar, the quality of hypertension management services among primary care providers is low, drastically reducing the effective coverage of these services (Figure 4.2). Only 16.78% of providers measured blood pressure more than one time, and among the providers who were able to accurately diagnose a hypertensive

patient, only 59.34% were able to write an appropriate prescription to safely lower blood pressure. Even more troubling is that 10.99% of providers wrote a prescription that would result in harm to the patient. Given that perceived quality is a key driver of care-seeking for hypertensive individuals in India, measures to improve the clinical quality of care provided by the public sector may improve utilization of these services (Kujawski et al. 2018; Chapter 3). This study reveals the lack of access to quality services for non-communicable diseases for the majority of the population in a large Indian state and suggests areas for improvement.

Figure 4.2: Effective coverage of hypertension management services in Bihar



Our findings add to the expanding body of literature that uses process quality to measure effective coverage of health services. Previous studies have demonstrated a quality gap in the effective coverage of antenatal care, family planning, and sick child care across eight LMICs (Hannah H Leslie et al. 2017). Our results suggest that the quality gap is not limited to services for reproductive, maternal, and child health, but also extend into services to manage non-

communicable diseases. Previous studies have reported no difference in the likelihood of giving a correct diagnosis or appropriate treatment between IPs and qualified primary providers for a few common conditions such as child pneumonia and asthma (Das et al. 2012). Our study demonstrates that public (formally trained) and private MBBS providers give significantly higher quality hypertension care than both IPs and private AYUSH providers in rural Bihar. This is problematic, as IPs and private providers are overwhelmingly the providers of choice in rural areas. IPs have demonstrated their ability to treat other common conditions such as diarrhea and childhood pneumonia at levels similar to formally trained providers, however there is a major quality gap in their ability to manage hypertension. As the burden of disease in LMICs continues to shift towards non-communicable diseases, the quality of services to diagnose and manage conditions such as hypertension must be better studied and improved. Future efforts to study service quality through vignettes, standardized patients, and direct observation should include modules on hypertension management and services to manage other high-priority non-communicable diseases.

This study also improves the measurement of effective coverage for services to manage non-communicable diseases. Previous efforts have either focused on controlling blood pressure among specific populations such as the elderly (Y Zhao et al. 2020) or have focused on one aspect of hypertension management such as screening services (Charoendee et al. 2018). The HMSCI can be constructed at subnational levels and within subgroups, and also focuses on a range of hypertension management services spanning several target populations (e.g. screening for all adult populations and pharmaceutical treatment and lifestyle advice for diagnosed hypertensives). All previous efforts to measure effective coverage of hypertension management

services have suffered due to a lack of consensus on a single metric, despite the importance that is placed on measuring coverage of hypertension management services (Agyepong and Murray 2018). Several indices for monitoring progress towards UHC exclude hypertension management, citing reasons such as “insufficient data”. As household surveys become more robust and begin to include biometric data and other indicators of hypertension management coverage, now is the perfect time to reach consensus on a measurement of effective coverage for hypertension management services.

There are several limitations to this study. First, the HMSCI does not account for population-level preventive interventions, like salt reduction in processed foods or air quality improvement, which may have significant impacts on population-level hypertension prevalence and blood pressure control. It also does not account for population adherence to prescribed lifestyle advice treatment, which is a necessary condition for achieving blood pressure control. However, by incorporating the quality of the services provided by the public and private health sectors in India, the HMSCI indicates the level of health gain that can be achieved from services delivered specifically by the health system. The rapidly changing body of evidence related to hypertension management means that certain indicators and sub-items, such as measuring blood pressure twice during a clinical visit, may have reduced importance within the overall index (Lu et al. 2021). It will be important to further refine the HMSCI based on inputs from global and local experts to ensure that it reflects the most important aspects of hypertension management. A second limitation has to do with the measurement strategies used in this study. The APHCB study did not include the measurement of biometric data (such as blood pressure), necessitating the use of additional data sources to estimate the percent of individuals with raised blood

pressure who were aware of their diagnosis. Future attempts to replicate the HMSCI can use data from a single household survey and directly measure the percent of the population who is aware of their hypertension diagnosis. Although there is a 5-year time lag between the NFHS-4 and the APHCB, preliminary results released from the NFHS-5 study have demonstrated that hypertension prevalence is increasing in rural Bihar, suggesting that our calculations for awareness of hypertension diagnosis are likely an underestimate of the current situation. Third, the APHCB found that hypertensive individuals traveled an average of 18.1 kilometers for hypertension care, and that 36.3% of all individuals linked to care bypassed local options to manage their hypertension. Geographically linking individuals to providers at a local level may be inappropriate as individuals may not receive care from these providers, however by using division-wide averages of quality, we believe we are using a sufficiently broad geographic area to link these individuals to quality estimates representative of their true source of care (M. A. Peters et al. 2020).

Conclusion

This is the first attempt to describe an overall indicator of effective coverage for a range of best-practice services associated with hypertension management in a low- or middle-income country. The need for such an indicator is dire, as hypertension continues to add to the burden of disease across the world and its successful management is an integral component of health systems that achieve UHC. The HMSCI is designed to address shortcomings in the current measurement of effective coverage for hypertension management services. It's application to rural Bihar suggests areas to improve the quality of hypertension diagnosis and treatment services at the primary care level. More broadly, the HMSCI is a starting point towards reaching consensus on a single

indicator for measuring a health system's ability to provide the range of effective hypertension management services that improve population health.

Chapter 5: Conclusion

As the mantra, "what gets measured gets managed" suggests, the first step to improving hypertension management services in LMICs is to agree on the measurement methods used to evaluate health systems performance. This thesis contributes to the improvement of population health by developing and applying methods to evaluate the coverage of quality hypertension management services in low-resource settings. The following chapter highlights main findings from each of the three studies, describes strengths and limitations of the overall dissertation, proposes areas for future research and policy recommendations, and offers some concluding remarks.

Synthesis Narrative

Despite the steadily rising burden of NCDs, including hypertension, in LMICs, there have been few efforts to prepare health systems to address these health risks. While methods of measuring health system performance are increasingly being developed to monitor the effective coverage of interventions to improve maternal and child health and reduce the impact of communicable diseases, NCDs are being neglected. The basis for this dissertation is the conceptual framework through which contextual, individual, and health system factors modify an individual's hypertension management experience and ultimately influence the extent to which an individual can experience improved health (Figure 1.3). This work focuses on the health system's role in improving health, and advances methods of evaluating health system provision of quality hypertension management services. The thesis develops a framework for measuring gaps along the hypertension care continuum, applies the framework to rural Bihar, India to identify key bottlenecks to providing quality hypertension care, and proposes an improved method for

measuring effective coverage of hypertension management services based on the observed bottlenecks.

The first aim of this research develops a measurement framework for tracking effective coverage of hypertension management based on a review of how effective coverage and quality-adjusted measures of hypertension management services have been previously described. Although there are at least eight studies that have reported effective coverage of hypertension-related services, there is no consensus on how effective coverage is defined, making comparison between and within countries difficult. Studies that calculate effective coverage of hypertension management within the same country show a wide variation in effective coverage estimates, indicating that methodological differences have a substantial impact on these assessments. Further, these studies primarily focus on outcome measures of quality which are often heavily influenced by social determinants of health. This dependence on outcome quality neglects important structural and process-related factors that determine the quality of care received by individuals. The only study that incorporates process quality in the definition of effective coverage focuses on one aspect of hypertension management (i.e. blood pressure measurement), suggesting that more work is needed to develop comprehensive effective coverage metrics (Charoendee et al. 2018). While there are several studies that measure the quality of hypertension management services received at the population level, none attempts to calculate a quality-adjusted coverage score for hypertension management services. As a result, the coverage of high-quality hypertension management services in LMICs is largely unknown. Those studies that did report on process quality demonstrate major gaps in provider fidelity to protocols (both in terms of blood pressure measurement and treatment) and patient adherence to medicines. Therefore, an expanded

hypertension care cascade is proposed with additional steps to formalize the inclusion of screening among the general population, to include linkage to quality care (i.e., care that follows treatment protocols), and to include patient adherence to medicines. The final expanded hypertension cascade of care is based on the findings of the scoping review and can be used to identify barriers to achieving effective hypertension management in LMICs.

Chapter two's results suggest that while many studies quantify the prevalence of hypertension and coverage of screening and treatment services in LMICs, few examine the content of services provided during these visits. The second aim of this research is to apply the expanded hypertension cascade of care framework to a low-resource setting: rural Bihar, India. Applying the expanded hypertension cascade of care to data collected from households confirms the findings of previous studies: that the majority of hypertensive individuals in rural Bihar have either never had their blood pressure measured (~22% of hypertensive individuals) or had been previously screened but remained undiagnosed (~47% of hypertensive individuals). Of those hypertensive individuals linked to any care, as few as 19% were linked to providers who were able to accurately diagnose hypertension and prescribe appropriate treatment. This suggests that the additional steps (linkage to quality care and adherence to treatment) are essential for understanding barriers to effective hypertension management in rural Bihar. Further, the study's analysis of hypertension management services suggests that the quality of hypertension care in rural Bihar is substandard in multiple regards. In terms of structural quality, 40% of all providers are not able to offer a single front-line antihypertensive medication. Direct observations of patient visits reveal that only 30% of all adults are being opportunistically screened for high blood pressure during routine primary care visits. Further, in terms of provider knowledge, only

a fifth of providers know to check blood pressure twice during a patient visit and among the providers who correctly diagnose hypertension, 40% of prescriptions written to treat hypertension are inappropriate for lowering blood pressure (including 11% of prescriptions that could cause harm to the patient), and less than 5% of providers are explaining the lifelong nature and treatment needs of hypertension to newly diagnosed patients. This supply-side information supplements the traditional demand-side cascade of care analysis and provides important insights as to why individuals are lost along the hypertension cascade of care, namely because providers do not have the structural capacity or demonstrate the knowledge to be able to administer the quality care that will result in early diagnosis and successful treatment of high blood pressure.

While the second research aim provides key and novel insights as to why individuals are not able to receive the potential health benefits from hypertension management services in rural Bihar, it does not provide a method for reporting the effective coverage of these services. The third research aim addresses the shortcomings of previous effective coverage metrics and proposes an index measure of effective coverage that captures the major gaps identified in rural Bihar's expanded hypertension cascade of care. The new metric incorporates the coverage of multiple services associated with effective hypertension management (i.e. screening, diagnosis, and treatment). The metric also incorporates dimensions of service quality which were found to be inadequate in the first and second research aims (i.e. facility readiness, examinations, diagnosis, prescription, and advice). When applied to rural Bihar, the index suggests that while the coverage of various hypertension management services is generally high, the quality of these services is low, reducing the potential health gains that can be experienced by the population. A further examination of hypertension service quality demonstrates that public providers and

private MBBS doctors provide significantly better-quality hypertension care than private AYUSH providers and informal providers. This index can be used by policymakers to improve hypertension services (e.g. by helping to prioritize expansion of coverage or improvement of service quality) and fills the need for an effective coverage metric for hypertension services, which is currently absent within the UHC tracking framework.

Taken together, this dissertation suggests that the process quality of hypertension management services is substandard and requires more attention in Bihar and other low-resource contexts. This work has implications at several levels. For individuals, it is important to note that public providers give superior hypertension care in rural Bihar. Although individual preference for hypertension management in rural Bihar is skewed towards private providers due to a perceived lack of quality in public facilities, our results suggest that most patients can receive higher quality hypertension care for free (and usually closer to home) if they attend their local PHCs. Community awareness of hypertension should be expanded, to generate demand for higher quality services, which may in turn force informal providers and other providers to improve their hypertension-related knowledge. Local policymakers in Bihar should recognize the importance of improving the quality of hypertension management services (rather than prioritizing the expansion of service coverage alone). Finally, the broader public health audience should recognize the benefits of using the expanded cascade of care and of further developing the proposed effective coverage index to study hypertension management and improve efforts to monitor progress towards UHC. These findings should be interpreted within the strengths and limitations of the research effort.

Strengths and Limitations

While the strengths and limitations of individual studies have been previously described, it is also important to consider the relative strengths and limitations of the overall thesis.

This thesis employs a mixed method, exploratory sequential study design with a focus on quantitative methods (Creswell and Plano Clark 2006). The sequential study design means that the insights gained from the scoping literature review are incorporated in the measurement framework, which in turn informs the key dimensions to be included in the final index of effective coverage. This comprehensive approach to metric development results in an evidence-based, high quality measure of effective coverage for hypertension management services. Another key strength of the study is the linked household and provider survey design. The provider survey's sampling frame is sourced from responses given to the household survey. This study design enables analysis on both the supply- and demand-side characteristics of hypertension management, and further enables direct linking of individuals to the providers from whom they receive care, a powerful tool for measuring effective coverage of health services (Do et al. 2016). Additionally, the study collects information on private providers, including informally trained providers, which are an important source of primary care in Bihar and other LMICs but are often excluded from health services research. The findings of this thesis are representative of the rural population and primary health care providers for the entire state of Bihar - a population of nearly 92 million people. The immediate external validity of this study therefore applies to a large population, suggesting that the findings are generalizable to a broad population of similar characteristics.

Several innovations also contribute to the strength of the thesis. To our knowledge, this is the first study to use a clinical vignette to study provider knowledge of hypertension case management in LMICs. Although frequently used to study provider knowledge, vignettes have historically focused on treating maternal and child health conditions or communicable diseases. This study is also the first attempt to design an index of effective coverage for multiple services associated with treating single health condition. While several indices exist to measure the effective coverage of services across a health system, such a composite measure has not been developed to capture the numerous services associated with managing a single health condition. Furthermore, this is one of only a few studies that has attempted to incorporate structural and process service quality into a measure of effective coverage or quality-adjusted coverage of services more broadly (Hannah H Leslie et al. 2017). This thesis, therefore, adds to the growing body of research on high quality health systems in LMICs, and is distinguished as one of the early NCD-focused contributions to the field. There are also some important limitations to the study that must be considered.

The first group of limitations is shaped by the design of the broader Assessment of Primary Health Care in Bihar study. Since the study did not collect information on the quality of providers that were visited by patients but were located beyond 5 kilometers from the home, the quality of care given by these providers is unknown. As a result, the true effective coverage of the entire health system (including urban providers) cannot be calculated. More broadly, the results of both the household survey and the provider survey are not generalizable to the urban population in Bihar. Bihar's population is 89% rural, so this is not a major issue for generalizability within the state, but it does hinder the generalizability of findings to urban

contexts, which may experience different levels of prevalence of high blood pressure and of coverage and/or quality of hypertension management services. Next, there was additional data that could have further benefitted the dissertation but were not within the scope of the parent study's household survey. These data include (i) multiple biometric blood pressure measurements taken during the household survey, (ii) detailed information on when patients last had their blood pressure measured and by whom, (iii) detailed information on when and how patients were diagnosed as hypertensive (e.g. upon admission to hospital or by a community health worker), (iv) detailed information on patient adherence to medicine and treatment, and (v) information on patient knowledge, attitudes, and practices about hypertension and relevant lifestyle modifications. Another notable limitation is the fact that the thesis only focuses on hypertension management services, and does not consider preventive interventions. While these preventive measures are essential for hypertension management and control, there was no scope to collect additional information in the household or provider surveys on interventions. Finally, the study was designed to be able to compare the knowledge of providers (through clinical vignettes) with the practice of providers (through direct observation), however the number of patients who presented to clinics for hypertension care while observations were ongoing (four visits) was insufficient to conduct this analysis. This number was influenced in part by the changes to data collection procedures after the COVID-19 pandemic.

Additional limitations were related to external factors that may have influenced the data that was collected. First, data collection for both the household survey and the provider quality assessment was interrupted by the COVID-19 pandemic. For the household survey, the only COVID-19 related interruption was to the "follow-up" phase of data collection, where

subsequent visits were scheduled with households that were selected to respond to the household survey but were not present during the first round of data collection. Conducting the "follow-up" phase would have improved response rates among households which were not present during the first visit and would have reduced non-response bias. The provider survey was paused after 28 of the 70 sampled villages were visited, and data collection was resumed nearly one calendar year later. During this time, we noted that several providers identified in the household survey one year prior had either stopped practicing medicine, permanently moved from the village in which they formerly practiced, or died. If COVID-19 changed provider practices, then there may be systematic differences between the data collected pre- and post-COVID-19 interruption. However, to protect enumerators and patients, the direct observation component of the provider assessment was abandoned after data collection was resumed, and it is less likely that COVID-19 changed provider knowledge (which would be reflected in the clinical vignettes) than provider practices. Another important contextual factor that might have impacted data collection was the Citizenship Amendment Act, which discriminated against Muslim Indians, causing distrust among predominantly Muslim communities, which reduced their participation in our household survey. Our household survey may therefore underrepresent Muslim populations, which would be problematic if those not included in our study have different characteristics than the populations included in our study.

Recommendations for Future Research

This dissertation lays the foundation for several important research activities which fall into three broad categories: replicating the research processes of this thesis, studying the expanded hypertension cascade of care in greater depth, and further advancing measures of effective coverage. The first broad category involves replicating the research processes described in this

thesis for other disease conditions and/or for hypertension in other contexts. By following the research process employed in this dissertation (i.e. conducting a scoping review to develop an evidence-based cascade of care, applying the cascade to identify major gaps, and developing an effective coverage index that measures the coverage and process quality of key services), the measurement of effective coverage can be improved for other understudied NCDs. Additionally, the process of applying the expanded cascade of care, followed by calculating the effective coverage index in other contexts can be useful to identify patterns in gaps and evaluate the effective coverage of hypertension management services across multiple contexts. This would add to the growing knowledge base on areas where governments need to intervene to improve coverage of effective hypertension management services.

The second potential area for future research involves studying the entire expanded cascade of care in depth. This dissertation provides great insight into the quality of hypertension management services, but it does not indicate the kinds of patient or provider characteristics that are associated with better adherence to treatment. Protocols have already been designed to describe the factors associated with medication adherence among hypertensive patients in LMICs (Agbor, Takah, and Aminde 2018). Future studies, ideally longitudinal in nature, would help to understand the kinds of care that improve patient adherence and ultimately blood pressure control. Longitudinal studies that follow a cohort of pre-hypertensive individuals over time could collect data on what kinds of care individuals receive, who develops hypertension (and who among the hypertensives eventually achieves blood pressure control), and where along the cascade of care most of these people are lost. Such longitudinal studies are essential for understanding the service delivery strategies that are necessary for achieving ideal health

outcomes, especially normal blood pressure levels. These studies would also help to understand how frequently individuals with high blood pressure fluctuate between normo- and hypertension over time, which would provide important evidence either in favor of or against the use of using cross-sectional surveys to determine outcome measures for measuring effective coverage of hypertension management services.

Finally, future studies can help to further advance the hypertension management service coverage index. It is essential to gain consensus from stakeholders (including public health experts, physicians, and patients) about the specific components that should contribute to the final index. A Delphi study on the essential services and quality metrics that should be included in the index could be conducted to reach such a consensus in a systematic way. Other studies can continue to advance the methodology of the index, by (i) testing and validating new, more exact techniques to link patients with providers, (ii) weighting the service quality components by relative importance to health outcomes, (iii) calculating the effective coverage of services for population subgroups (e.g. by caste, by religion, and/or by sex), and (iv) validating the index with other measures that indicate effective coverage of service. Finally, future studies on tracking effective coverage within health systems should incorporate the hypertension management service coverage index to ensure that services to measure hypertension are incorporated in overall assessments of health systems performance.

Policy Recommendations

This research has several important policy implications that exist at multiple levels of implementation. At the local level in Bihar, while the quality of hypertension management care

given by public providers is significantly better than informal providers or private AYUSH providers, there is still much room for improvement. The government should institute trainings to address knowledge gaps of these providers and should work to ensure that supply chains are strengthened so that all PHCs have a steady supply of first line antihypertensive medications. Although some government officials are reluctant to engage the private sector (especially informal providers), these findings suggest that key opportunities to screen and diagnose individuals are being missed. If private sector providers can be trained to regularly measure patient blood pressure, and referral pathways are formalized with government providers so that suspected cases are referred to the local PHC, hypertension can be detected much earlier, and treatment can be initiated sooner, resulting in improved health for individuals and greater savings for health systems (due to reduced strokes or severe events associated with advanced hypertension). Additionally, awareness of hypertension among community members should be increased so that there is a greater demand for high quality services and so that the community becomes knowledgeable about the lifestyle modifications that can reduce the risk of developing hypertension and improve non-pharmaceutical blood pressure treatment.

At the state-level, this study has important implications, especially within the context of the Ayushman Bharat (AB) comprehensive health reform scheme. The first component under the AB scheme is to create 150,000 health and wellness centers (HWC) across the country to deliver comprehensive primary health care. These HWCs are envisioned to deliver an expanded range of services with particular emphasis on addressing non-communicable diseases (Ministry of Health & Family Welfare 2019). The results of this study demonstrate that the government does not necessarily need to expand services in rural Bihar, but rather should focus on improving the

quality of services already in existence. If these HWC are staffed by individuals who provide lower quality care, they will not be improving upon the services currently available in rural Bihar, since the coverage of services is already generally high. Hence, special efforts must be made to ensure that the quality of care provided at HWCs is sufficiently high and that HWCs are promoted as additional, high quality options to ensure that there is demand in the community for these services.

Finally, at the national and global level, this study suggests that the process quality of hypertension management services may be low in many contexts. The measurement of blood pressure levels alone may be hiding substandard service quality, as individuals who are predisposed to achieving blood pressure control may do so with relatively little intervention from the health system. Given the rapidly increasing burden of disease, there must be a global commitment to study and improve hypertension management services in LMICs. As the global population of individuals in need of blood pressure management services increases, it is imperative that health systems and individual providers are knowledgeable and prepared to provide these essential services. An important step to demonstrating this commitment at the global level is to ensure that services to manage hypertension are included in all future UHC tracking indices.

Concluding Remarks

This dissertation contributes to the management and measurement of health systems performance related to providing hypertension management services. The process quality of hypertension management services is not well studied, but deserves attention in health systems research, as it reflects the impact of services provided rather than outcomes which can be heavily influenced by

social determinants of health. Even in rural Bihar, access to hypertension services (once diagnosed) is high, however people are not screened for high blood pressure frequently enough, resulting in delayed diagnosis. The quality of hypertension care provided in Bihar is substandard. While most primary care providers have the ability to diagnose hypertension, there are significant gaps in their ability to measure blood pressure in patients according to internationally recognized standards, give lifestyle advice, and write appropriate prescriptions for safely lowering blood pressure.

The dissertation develops a generic, evidence-based measurement framework for quantifying gaps along the hypertension care cascade, applies the framework to a low-resource setting (rural Bihar, India) to describe the health system-related factors that contribute to these gaps, and finally proposes a single index measure for tracking and improving effective coverage of hypertension management services over time. Without appropriate measures of health system performance, there is no way of knowing whether the interventions that can improve quality of life are being delivered to those in need. This research can help to bridge the gap between health systems metrics and ensuring freedom from avoidable ill health due to hypertension for millions of people around the world.

Appendices

Annex 1: Assessment of Primary Health Care in Bihar Sample Size Calculations

Sample size calculation to detect differences in care seeking preferences among households

Stata code: power twoprop .5, diff(.05 .1)

Estimated sample sizes for a two-sample proportions test
Pearson's chi-squared test
Ho: p2 = p1 versus Ha: p2 != p1

Alpha	Power	N	N1	N2	Delta	P1	P2	Difference
.05	.8	3130	1565	1565	.05	.5	.55	.05
.05	**.8**	**776**	**388**	**388**	**.1**	**.5.**	**6**	**.1**

776 * 2 (design effect) = 1,552
1,552 / 0.66 (percent of sick patients who sought care) = 2,351.5
2,352 / 0.06 (percent of individuals who were sick in last two weeks) = 39,191.6 individuals
39,191.6 / 5 (average household size) = 7,838.3 households
7,838.3 / 0.8 (20% non-response rate) = 9,797.9 households

Sample size calculation to detect differences in quality across public and private providers

Stata code: power twomeans 57, sd(7.25) diff(5(5)15)

Estimated sample sizes for a two-sample means test
t test assuming sd1 = sd2 = sd
Ho: m2 = m1 versus Ha: m2 != m1

Alpha	Power	N	N1	N2	Delta	M1	M2	Difference	Standard Deviation
.05	**.8**	**68**	**34**	**34**	**5**	**57**	**62**	**5**	**7.25**
.05	.8	20	10	10	10	57	67	10	7.25
.05	.8	10	5	5	15	57	72	15	7.25

34 public facilities and 34 private facilities required
35 * 1.5 (DEFT) = 52.5
52.5 / 0.8 (20% non-response rate) = 65.6 PHCs

Annex 2: Scoping Review Search Strategy

Search conducted on 12 October, 2020

Database	Effective Coverage	N	Care Cascade	N	Combined	N
SCOPUS	TITLE-ABS-KEY (“effective coverage” AND “hypertension”)	13	TITLE-ABS-KEY (“effective coverage” AND “hypertension”)	201	TITLE-ABS-KEY (hypertension) AND (TITLE-ABS-KEY ("effective coverage") OR (TITLE-ABS-KEY (cascade AND care)))	218
EMBASE	**hypertension**:ti,ab,kw AND **‘effective coverage’**:ti,ab,kw	15	**hypertension**:ti,ab,kw AND **cascade**:ti,ab,kw AND **care**:ti,ab,kw	121	hypertension:ti,ab,kw AND 'effective coverage':ti,ab,kw OR 'care cascade':ti,ab,kw OR 'cascade of care':ti,ab,kw	892
PubMed	(hypertension) AND (‘effective coverage’)	492	(hypertension) AND (care) AND (cascade)	158	(hypertension) AND ((care) AND (cascade)) OR ("effective coverage")	486
ScienceDirect	“hypertension” AND “effective coverage”	81	Title, abstract, keywords: “hypertension” AND “cascade”	363	“hypertension” AND “effective coverage” OR ("care cascade" OR "cascade of care")	719
ProQuest	hypertension AND “effective coverage”	370	noft(hypertension) AND care AND noft(cascade)	397	noft(hypertension) AND noft("effective coverage") OR noft("care cascade" OR "cascade of care")	510
Web of Science	**ALL FIELDS:** (hypertension) *AND* **ALL FIELDS:** ("effective coverage")	13	**ALL FIELDS:** (hypertension) *AND* **ALL FIELDS:** ("care cascade") *OR* **ALL FIELDS:** ("cascade of care")	289	**ALL FIELDS:** (hypertension) *AND* **ALL FIELDS:** ("care cascade") *OR* **ALL FIELDS:** ("cascade of care") *OR* **ALL FIELDS:** ("effective coverage")	881

Search conducted on 26 October, 2020 to add hypertension prevalence, awareness, control to search

Search tags for LMICs were sourced from the Cochrane library: https://epoc.cochrane.org/lmic-filters

Searched for “hypertension” AND “prevalence” OR “awareness” AND “treatment” and “control” and “LMIC” in title/abstract

Embase search terms below- 589 articles returned

hypertension:ab,ti AND (prevalence:ab,ti OR awareness:ab,ti) AND treatment:ab,ti AND control:ab,ti AND (afghanistan:ti,ab,kw OR albania:ti,ab,kw OR algeria:ti,ab,kw OR (american:ti,ab,kw AND samoa:ti,ab,kw) OR angola:ti,ab,kw OR 'antigua and barbuda':ti,ab,kw OR antigua:ti,ab,kw OR barbuda:ti,ab,kw OR argentina:ti,ab,kw OR armenia:ti,ab,kw OR armenian:ti,ab,kw OR aruba:ti,ab,kw OR azerbaijan:ti,ab,kw OR bahrain:ti,ab,kw OR bangladesh:ti,ab,kw OR barbados:ti,ab,kw OR (republic:ti,ab,kw AND of:ti,ab,kw AND belarus:ti,ab,kw) OR belarus:ti,ab,kw OR byelarus:ti,ab,kw OR

belorussia:ti,ab,kw OR byelorussian:ti,ab,kw OR belize:ti,ab,kw OR (british:ti,ab,kw AND honduras:ti,ab,kw) OR benin:ti,ab,kw OR dahomey:ti,ab,kw OR bhutan:ti,ab,kw OR bolivia:ti,ab,kw OR 'bosnia and herzegovina':ti,ab,kw OR bosnia:ti,ab,kw OR herzegovina:ti,ab,kw OR botswana:ti,ab,kw OR bechuanaland:ti,ab,kw OR brazil:ti,ab,kw OR brasil:ti,ab,kw OR bulgaria:ti,ab,kw OR (burkina:ti,ab,kw AND faso:ti,ab,kw) OR (burkina:ti,ab,kw AND fasso:ti,ab,kw) OR (upper:ti,ab,kw AND volta:ti,ab,kw) OR burundi:ti,ab,kw OR urundi:ti,ab,kw OR (cabo:ti,ab,kw AND verde:ti,ab,kw) OR (cape:ti,ab,kw AND verde:ti,ab,kw) OR cambodia:ti,ab,kw OR kampuchea:ti,ab,kw OR (khmer:ti,ab,kw AND republic:ti,ab,kw) OR cameroon:ti,ab,kw OR cameron:ti,ab,kw OR cameroun:ti,ab,kw OR (central:ti,ab,kw AND african:ti,ab,kw AND republic:ti,ab,kw) OR (ubangi:ti,ab,kw AND shari:ti,ab,kw) OR chad:ti,ab,kw OR chile:ti,ab,kw OR china:ti,ab,kw OR colombia:ti,ab,kw OR comoros:ti,ab,kw OR (comoro:ti,ab,kw AND islands:ti,ab,kw) OR (iles:ti,ab,kw AND comores:ti,ab,kw) OR mayotte:ti,ab,kw OR (democratic:ti,ab,kw AND republic:ti,ab,kw AND of:ti,ab,kw AND the:ti,ab,kw AND congo:ti,ab,kw) OR (democratic:ti,ab,kw AND republic:ti,ab,kw AND congo:ti,ab,kw) OR congo:ti,ab,kw OR zaire:ti,ab,kw OR (costa:ti,ab,kw AND rica:ti,ab,kw) OR (`cote:ti,ab,kw AND d:ti,ab,kw AND 'ivoire':ti,ab,kw) OR (`cote:ti,ab,kw AND d:ti,ab,kw AND 'ivoire':ti,ab,kw) OR (cote:ti,ab,kw AND divoire:ti,ab,kw) OR (cote:ti,ab,kw AND d:ti,ab,kw AND ivoire:ti,ab,kw) OR (ivory:ti,ab,kw AND coast:ti,ab,kw) OR croatia:ti,ab,kw OR cuba:ti,ab,kw OR cyprus:ti,ab,kw OR (czech:ti,ab,kw AND republic:ti,ab,kw) OR czechoslovakia:ti,ab,kw OR djibouti:ti,ab,kw OR (french:ti,ab,kw AND somaliland:ti,ab,kw) OR dominica:ti,ab,kw OR (dominican:ti,ab,kw AND republic:ti,ab,kw) OR ecuador:ti,ab,kw OR egypt:ti,ab,kw OR (united:ti,ab,kw AND arab:ti,ab,kw AND republic:ti,ab,kw) OR (el:ti,ab,kw AND salvador:ti,ab,kw) OR (equatorial:ti,ab,kw AND guinea:ti,ab,kw) OR (spanish:ti,ab,kw AND guinea:ti,ab,kw) OR eritrea:ti,ab,kw OR estonia:ti,ab,kw OR eswatini:ti,ab,kw OR swaziland:ti,ab,kw OR ethiopia:ti,ab,kw OR fiji:ti,ab,kw OR gabon:ti,ab,kw OR (gabonese:ti,ab,kw AND republic:ti,ab,kw) OR gambia:ti,ab,kw OR 'georgia (republic)':ti,ab,kw OR georgian:ti,ab,kw OR ghana:ti,ab,kw OR (gold:ti,ab,kw AND coast:ti,ab,kw) OR gibraltar:ti,ab,kw OR greece:ti,ab,kw OR grenada:ti,ab,kw OR guam:ti,ab,kw OR guatemala:ti,ab,kw OR (guinea:ti,ab,kw AND bissau:ti,ab,kw) OR guyana:ti,ab,kw OR (british:ti,ab,kw AND guiana:ti,ab,kw) OR haiti:ti,ab,kw OR hispaniola:ti,ab,kw OR honduras:ti,ab,kw OR hungary:ti,ab,kw OR india:ti,ab,kw OR indonesia:ti,ab,kw OR timor:ti,ab,kw OR iran:ti,ab,kw OR iraq:ti,ab,kw OR (isle:ti,ab,kw AND of:ti,ab,kw AND man:ti,ab,kw) OR jamaica:ti,ab,kw OR jordan:ti,ab,kw OR kazakhstan:ti,ab,kw OR kazakh:ti,ab,kw OR kenya:ti,ab,kw OR (`democratic:ti,ab,kw AND people:ti,ab,kw AND 's republic of korea':ti,ab,kw) OR (republic:ti,ab,kw AND of:ti,ab,kw AND korea:ti,ab,kw) OR (north:ti,ab,kw AND korea:ti,ab,kw) OR (south:ti,ab,kw AND korea:ti,ab,kw) OR korea:ti,ab,kw OR kosovo:ti,ab,kw OR kyrgyzstan:ti,ab,kw OR kirghizia:ti,ab,kw OR kirgizstan:ti,ab,kw OR (kyrgyz:ti,ab,kw AND republic:ti,ab,kw) OR kirghiz:ti,ab,kw OR laos:ti,ab,kw OR (lao:ti,ab,kw AND pdr:ti,ab,kw) OR (`lao:ti,ab,kw AND people:ti,ab,kw AND 's democratic republic':ti,ab,kw) OR latvia:ti,ab,kw OR lebanon:ti,ab,kw OR (lebanese:ti,ab,kw AND republic:ti,ab,kw) OR lesotho:ti,ab,kw OR basutoland:ti,ab,kw OR liberia:ti,ab,kw OR libya:ti,ab,kw OR (libyan:ti,ab,kw AND arab:ti,ab,kw AND jamahiriya:ti,ab,kw) OR lithuania:ti,ab,kw OR macau:ti,ab,kw OR macao:ti,ab,kw OR (republic:ti,ab,kw AND of:ti,ab,kw AND north:ti,ab,kw AND macedonia:ti,ab,kw) OR macedonia:ti,ab,kw OR madagascar:ti,ab,kw OR (malagasy:ti,ab,kw AND republic:ti,ab,kw) OR malawi:ti,ab,kw OR nyasaland:ti,ab,kw OR malaysia:ti,ab,kw OR (malay:ti,ab,kw AND federation:ti,ab,kw) OR (malaya:ti,ab,kw AND federation:ti,ab,kw) OR maldives:ti,ab,kw OR (indian:ti,ab,kw AND ocean:ti,ab,kw AND islands:ti,ab,kw) OR (indian:ti,ab,kw AND ocean:ti,ab,kw) OR mali:ti,ab,kw OR malta:ti,ab,kw OR micronesia:ti,ab,kw OR (federated:ti,ab,kw AND states:ti,ab,kw AND of:ti,ab,kw AND micronesia:ti,ab,kw) OR kiribati:ti,ab,kw OR (marshall:ti,ab,kw AND islands:ti,ab,kw) OR nauru:ti,ab,kw OR (northern:ti,ab,kw AND mariana:ti,ab,kw AND islands:ti,ab,kw) OR palau:ti,ab,kw OR tuvalu:ti,ab,kw OR mauritania:ti,ab,kw OR mauritius:ti,ab,kw OR mexico:ti,ab,kw OR moldova:ti,ab,kw OR moldovian:ti,ab,kw OR mongolia:ti,ab,kw OR montenegro:ti,ab,kw OR 'montenegro (republic)':ti,ab,kw OR morocco:ti,ab,kw OR ifni:ti,ab,kw OR mozambique:ti,ab,kw OR (portuguese:ti,ab,kw AND east:ti,ab,kw AND africa:ti,ab,kw) OR myanmar:ti,ab,kw OR burma:ti,ab,kw OR namibia:ti,ab,kw OR nepal:ti,ab,kw OR (netherlands:ti,ab,kw AND antilles:ti,ab,kw) OR

nicaragua:ti,ab,kw OR niger:ti,ab,kw OR nigeria:ti,ab,kw OR oman:ti,ab,kw OR muscat:ti,ab,kw OR pakistan:ti,ab,kw OR panama:ti,ab,kw OR (papua:ti,ab,kw AND new:ti,ab,kw AND guinea:ti,ab,kw) OR (new:ti,ab,kw AND guinea:ti,ab,kw) OR paraguay:ti,ab,kw OR peru:ti,ab,kw OR philippines:ti,ab,kw OR philipines:ti,ab,kw OR phillipines:ti,ab,kw OR phillippines:ti,ab,kw OR poland:ti,ab,kw OR (`polish:ti,ab,kw AND people:ti,ab,kw AND 's republic':ti,ab,kw) OR portugal:ti,ab,kw OR (portuguese:ti,ab,kw AND republic:ti,ab,kw) OR (puerto:ti,ab,kw AND rico:ti,ab,kw) OR romania:ti,ab,kw OR russia:ti,ab,kw OR (russian:ti,ab,kw AND federation:ti,ab,kw) OR ussr:ti,ab,kw OR (soviet:ti,ab,kw AND union:ti,ab,kw) OR (union:ti,ab,kw AND of:ti,ab,kw AND soviet:ti,ab,kw AND socialist:ti,ab,kw AND republics:ti,ab,kw) OR rwanda:ti,ab,kw OR ruanda:ti,ab,kw OR samoa:ti,ab,kw OR (pacific:ti,ab,kw AND islands:ti,ab,kw) OR polynesia:ti,ab,kw OR (samoan:ti,ab,kw AND islands:ti,ab,kw) OR (navigator:ti,ab,kw AND island:ti,ab,kw) OR (navigator:ti,ab,kw AND islands:ti,ab,kw) OR 'sao tome and principe':ti,ab,kw OR (saudi:ti,ab,kw AND arabia:ti,ab,kw) OR senegal:ti,ab,kw OR serbia:ti,ab,kw OR seychelles:ti,ab,kw OR (sierra:ti,ab,kw AND leone:ti,ab,kw) OR slovakia:ti,ab,kw OR (slovak:ti,ab,kw AND republic:ti,ab,kw) OR slovenia:ti,ab,kw OR melanesia:ti,ab,kw OR (solomon:ti,ab,kw AND island:ti,ab,kw) OR (solomon:ti,ab,kw AND islands:ti,ab,kw) OR (norfolk:ti,ab,kw AND island:ti,ab,kw) OR (norfolk:ti,ab,kw AND islands:ti,ab,kw) OR somalia:ti,ab,kw OR (south:ti,ab,kw AND africa:ti,ab,kw) OR (south:ti,ab,kw AND sudan:ti,ab,kw) OR (sri:ti,ab,kw AND lanka:ti,ab,kw) OR ceylon:ti,ab,kw OR 'saint kitts and nevis':ti,ab,kw OR 'st. kitts and nevis':ti,ab,kw OR (saint:ti,ab,kw AND lucia:ti,ab,kw) OR 'st. lucia':ti,ab,kw OR 'saint vincent and the grenadines':ti,ab,kw OR (saint:ti,ab,kw AND vincent:ti,ab,kw) OR 'st. vincent':ti,ab,kw OR grenadines:ti,ab,kw OR sudan:ti,ab,kw OR suriname:ti,ab,kw OR surinam:ti,ab,kw OR (dutch:ti,ab,kw AND guiana:ti,ab,kw) OR (netherlands:ti,ab,kw AND guiana:ti,ab,kw) OR syria:ti,ab,kw OR (syrian:ti,ab,kw AND arab:ti,ab,kw AND republic:ti,ab,kw) OR tajikistan:ti,ab,kw OR tadjikistan:ti,ab,kw OR tadzhikistan:ti,ab,kw OR tadzhik:ti,ab,kw OR tanzania:ti,ab,kw OR tanganyika:ti,ab,kw OR thailand:ti,ab,kw OR siam:ti,ab,kw OR (timor:ti,ab,kw AND leste:ti,ab,kw) OR (east:ti,ab,kw AND timor:ti,ab,kw) OR togo:ti,ab,kw OR (togolese:ti,ab,kw AND republic:ti,ab,kw) OR tonga:ti,ab,kw OR 'trinidad and tobago':ti,ab,kw OR trinidad:ti,ab,kw OR tobago:ti,ab,kw OR tunisia:ti,ab,kw OR 'turkey (republic)':ti,ab,kw OR turkey:ti,ab,kw OR turkmenistan:ti,ab,kw OR turkmen:ti,ab,kw OR uganda:ti,ab,kw OR ukraine:ti,ab,kw OR uruguay:ti,ab,kw OR uzbekistan:ti,ab,kw OR uzbek:ti,ab,kw OR vanuatu:ti,ab,kw OR (new:ti,ab,kw AND hebrides:ti,ab,kw) OR venezuela:ti,ab,kw OR vietnam:ti,ab,kw OR (viet:ti,ab,kw AND nam:ti,ab,kw) OR (middle:ti,ab,kw AND east:ti,ab,kw) OR (west:ti,ab,kw AND bank:ti,ab,kw) OR gaza:ti,ab,kw OR palestine:ti,ab,kw OR yemen:ti,ab,kw OR yugoslavia:ti,ab,kw OR zambia:ti,ab,kw OR zimbabwe:ti,ab,kw OR (northern:ti,ab,kw AND rhodesia:ti,ab,kw) OR (global:ti,ab,kw AND south:ti,ab,kw) OR (africa:ti,ab,kw AND south:ti,ab,kw AND of:ti,ab,kw AND the:ti,ab,kw AND sahara:ti,ab,kw) OR 'sub saharan africa':ti,ab,kw OR (subsaharan:ti,ab,kw AND africa:ti,ab,kw) OR (africa,:ti,ab,kw AND central:ti,ab,kw) OR (central:ti,ab,kw AND africa:ti,ab,kw) OR (africa,:ti,ab,kw AND northern:ti,ab,kw) OR (north:ti,ab,kw AND africa:ti,ab,kw) OR (northern:ti,ab,kw AND africa:ti,ab,kw) OR magreb:ti,ab,kw OR maghrib:ti,ab,kw OR sahara:ti,ab,kw OR (africa,:ti,ab,kw AND southern:ti,ab,kw OR southern:ti,ab,kw) AND africa:ti,ab,kw OR (africa,:ti,ab,kw AND eastern:ti,ab,kw) OR (east:ti,ab,kw AND africa:ti,ab,kw) OR (eastern:ti,ab,kw AND africa:ti,ab,kw) OR (africa,:ti,ab,kw AND western:ti,ab,kw) OR (west:ti,ab,kw AND africa:ti,ab,kw) OR (western:ti,ab,kw AND africa:ti,ab,kw) OR (west:ti,ab,kw AND indies:ti,ab,kw) OR (indian:ti,ab,kw AND ocean:ti,ab,kw AND islands:ti,ab,kw) OR (caribbean:ti,ab,kw AND region:ti,ab,kw) OR (caribbean:ti,ab,kw AND islands:ti,ab,kw) OR caribbean:ti,ab,kw OR (central:ti,ab,kw AND america:ti,ab,kw) OR (latin:ti,ab,kw AND america:ti,ab,kw) OR 'south and central america':ti,ab,kw OR (south:ti,ab,kw AND america:ti,ab,kw) OR (asia,:ti,ab,kw AND central:ti,ab,kw) OR (central:ti,ab,kw AND asia:ti,ab,kw) OR (asia,:ti,ab,kw AND northern:ti,ab,kw) OR (north:ti,ab,kw AND asia:ti,ab,kw) OR (northern:ti,ab,kw AND asia:ti,ab,kw) OR (asia,:ti,ab,kw AND southeastern:ti,ab,kw) OR (southeastern:ti,ab,kw AND asia:ti,ab,kw) OR (south:ti,ab,kw AND eastern:ti,ab,kw AND asia:ti,ab,kw) OR (southeast:ti,ab,kw AND asia:ti,ab,kw) OR (south:ti,ab,kw AND east:ti,ab,kw AND asia:ti,ab,kw) OR (asia,:ti,ab,kw AND western:ti,ab,kw) OR

(western:ti,ab,kw AND asia:ti,ab,kw) OR (europe,:ti,ab,kw AND eastern:ti,ab,kw) OR (east:ti,ab,kw AND europe:ti,ab,kw) OR (eastern:ti,ab,kw AND europe:ti,ab,kw) OR (developing:ti,ab,kw AND country:ti,ab,kw) OR (developing:ti,ab,kw AND countries:ti,ab,kw) OR (developing:ti,ab,kw AND nation?:ti,ab,kw) OR (developing:ti,ab,kw AND population?:ti,ab,kw) OR (developing:ti,ab,kw AND world:ti,ab,kw) OR (less:ti,ab,kw AND developed:ti,ab,kw AND countr*:ti,ab,kw) OR (less:ti,ab,kw AND developed:ti,ab,kw AND nation?:ti,ab,kw) OR (less:ti,ab,kw AND developed:ti,ab,kw AND population?:ti,ab,kw) OR (less:ti,ab,kw AND developed:ti,ab,kw AND world:ti,ab,kw) OR (lesser:ti,ab,kw AND developed:ti,ab,kw AND countr*:ti,ab,kw) OR (lesser:ti,ab,kw AND developed:ti,ab,kw AND nation?:ti,ab,kw) OR (lesser:ti,ab,kw AND developed:ti,ab,kw AND population?:ti,ab,kw) OR (lesser:ti,ab,kw AND developed:ti,ab,kw AND world:ti,ab,kw) OR (under:ti,ab,kw AND developed:ti,ab,kw AND countr*:ti,ab,kw) OR (under:ti,ab,kw AND developed:ti,ab,kw AND nation?:ti,ab,kw) OR (under:ti,ab,kw AND developed:ti,ab,kw AND population?:ti,ab,kw) OR (under:ti,ab,kw AND developed:ti,ab,kw AND world:ti,ab,kw) OR (underdeveloped:ti,ab,kw AND countr*:ti,ab,kw) OR (underdeveloped:ti,ab,kw AND nation?:ti,ab,kw) OR (underdeveloped:ti,ab,kw AND population?:ti,ab,kw) OR (underdeveloped:ti,ab,kw AND world:ti,ab,kw) OR (middle:ti,ab,kw AND income:ti,ab,kw AND countr*:ti,ab,kw) OR (middle:ti,ab,kw AND income:ti,ab,kw AND nation?:ti,ab,kw) OR (middle:ti,ab,kw AND income:ti,ab,kw AND population?:ti,ab,kw) OR (low:ti,ab,kw AND income:ti,ab,kw AND countr*:ti,ab,kw) OR (low:ti,ab,kw AND income:ti,ab,kw AND nation?:ti,ab,kw) OR (low:ti,ab,kw AND income:ti,ab,kw AND population?:ti,ab,kw) OR (lower:ti,ab,kw AND income:ti,ab,kw AND countr*:ti,ab,kw) OR (lower:ti,ab,kw AND income:ti,ab,kw AND nation?:ti,ab,kw) OR (lower:ti,ab,kw AND income:ti,ab,kw AND population?:ti,ab,kw) OR (underserved:ti,ab,kw AND countr*:ti,ab,kw) OR (underserved:ti,ab,kw AND nation?:ti,ab,kw) OR (underserved:ti,ab,kw AND population?:ti,ab,kw) OR (underserved:ti,ab,kw AND world:ti,ab,kw) OR (under:ti,ab,kw AND served:ti,ab,kw AND countr*:ti,ab,kw) OR (under:ti,ab,kw AND served:ti,ab,kw AND nation?:ti,ab,kw) OR (under:ti,ab,kw AND served:ti,ab,kw AND population?:ti,ab,kw) OR (under:ti,ab,kw AND served:ti,ab,kw AND world:ti,ab,kw) OR (deprived:ti,ab,kw AND countr*:ti,ab,kw) OR (deprived:ti,ab,kw AND nation?:ti,ab,kw) OR (deprived:ti,ab,kw AND population?:ti,ab,kw) OR (deprived:ti,ab,kw AND world:ti,ab,kw) OR (poor:ti,ab,kw AND countr*:ti,ab,kw) OR (poor:ti,ab,kw AND nation?:ti,ab,kw) OR (poor:ti,ab,kw AND population?:ti,ab,kw) OR (poor:ti,ab,kw AND world:ti,ab,kw) OR (poorer:ti,ab,kw AND countr*:ti,ab,kw) OR (poorer:ti,ab,kw AND nation?:ti,ab,kw) OR (poorer:ti,ab,kw AND population?:ti,ab,kw) OR (poorer:ti,ab,kw AND world:ti,ab,kw) OR (developing:ti,ab,kw AND econom*:ti,ab,kw) OR (less:ti,ab,kw AND developed:ti,ab,kw AND econom*:ti,ab,kw) OR (lesser:ti,ab,kw AND developed:ti,ab,kw AND econom*:ti,ab,kw) OR (under:ti,ab,kw AND developed:ti,ab,kw AND econom*:ti,ab,kw) OR (underdeveloped:ti,ab,kw AND econom*:ti,ab,kw) OR (middle:ti,ab,kw AND income:ti,ab,kw AND econom*:ti,ab,kw) OR (low:ti,ab,kw AND income:ti,ab,kw AND econom*:ti,ab,kw) OR (lower:ti,ab,kw AND income:ti,ab,kw AND econom*:ti,ab,kw) OR (low:ti,ab,kw AND gdp:ti,ab,kw) OR (low:ti,ab,kw AND gnp:ti,ab,kw) OR (low:ti,ab,kw AND gross:ti,ab,kw AND domestic:ti,ab,kw) OR (low:ti,ab,kw AND gross:ti,ab,kw AND national:ti,ab,kw) OR (lower:ti,ab,kw AND gdp:ti,ab,kw) OR (lower:ti,ab,kw AND gnp:ti,ab,kw) OR (lower:ti,ab,kw AND gross:ti,ab,kw AND domestic:ti,ab,kw) OR (lower:ti,ab,kw AND gross:ti,ab,kw AND national:ti,ab,kw) OR lmic:ti,ab,kw OR lmics:ti,ab,kw OR (third:ti,ab,kw AND world:ti,ab,kw) OR (lami:ti,ab,kw AND countr*:ti,ab,kw) OR (transitional:ti,ab,kw AND countr*:ti,ab,kw) OR (emerging:ti,ab,kw AND economies:ti,ab,kw) OR (emerging:ti,ab,kw AND nation?:ti,ab,kw))

Pubmed search terms below- 750 articles returned

(hypertension[Title/Abstract]) AND (prevalence[Title/Abstract] OR awareness[Title/Abstract]) AND (treatment[Title/Abstract]) AND (control[Title/Abstract]) AND (afghanistan[MeSH] OR albania[MeSH] OR algeria[MeSH] OR american samoa[MeSH] OR angola[MeSH] OR antigua and barbuda[MeSH] OR

argentina[MeSH] OR armenia[MeSH] OR aruba[MeSH] OR azerbaijan[MeSH] OR bahrain[MeSH] OR bangladesh[MeSH] OR barbados[MeSH] OR republic of belarus[MeSH] OR belize[MeSH] OR benin[MeSH] OR bhutan[MeSH] OR bolivia[MeSH] OR bosnia and herzegovina[MeSH] OR botswana[MeSH] OR brazil[MeSH] OR bulgaria[MeSH] OR burkina faso[MeSH] OR burundi[MeSH] OR cabo verde[MeSH] OR cambodia[MeSH] OR cameroon[MeSH] OR central african republic[MeSH] OR chad[MeSH] OR chile[MeSH] OR china[MeSH] OR colombia[MeSH] OR comoros[MeSH] OR democratic republic of the congo[MeSH] OR congo[MeSH] OR costa rica[MeSH] OR cote d'ivoire[MeSH] OR croatia[MeSH] OR cuba[MeSH] OR cyprus[MeSH] OR czech republic[MeSH] OR djibouti[MeSH] OR dominica[MeSH] OR dominican republic[MeSH] OR ecuador[MeSH] OR egypt[MeSH] OR el salvador[MeSH] OR equatorial guinea[MeSH] OR eritrea[MeSH] OR estonia[MeSH] OR swaziland[MeSH] OR ethiopia[MeSH] OR fiji[MeSH] OR gabon[MeSH] OR gambia[MeSH] OR georgia (republic)[MeSH] OR ghana[MeSH] OR gibraltar[MeSH] OR greece[MeSH] OR grenada[MeSH] OR guam[MeSH] OR guatemala[MeSH] OR guinea[MeSH] OR guinea bissau[MeSH] OR guyana[MeSH] OR haiti[MeSH] OR honduras[MeSH] OR hungary[MeSH] OR india[MeSH] OR indonesia[MeSH] OR iran[MeSH] OR iraq[MeSH] OR jamaica[MeSH] OR jordan[MeSH] OR kazakhstan[MeSH] OR kenya[MeSH] OR democratic people's republic of korea[MeSH] OR republic of korea[MeSH] OR kosovo[MeSH] OR kyrgyzstan[MeSH] OR laos[MeSH] OR latvia[MeSH] OR lebanon[MeSH] OR lesotho[MeSH] OR liberia[MeSH] OR libya[MeSH] OR lithuania[MeSH] OR macau[MeSH] OR republic of north macedonia[MeSH] OR madagascar[MeSH] OR malawi[MeSH] OR malaysia[MeSH] OR indian ocean islands[MeSH] OR mali[MeSH] OR malta[MeSH] OR micronesia[MeSH] OR palau[MeSH] OR mauritania[MeSH] OR mauritius[MeSH] OR mexico[MeSH] OR moldova[MeSH] OR mongolia[MeSH] OR montenegro[MeSH] OR morocco[MeSH] OR mozambique[MeSH] OR myanmar[MeSH] OR namibia[MeSH] OR nepal[MeSH] OR netherlands antilles[MeSH] OR nicaragua[MeSH] OR niger[MeSH] OR nigeria[MeSH] OR oman[MeSH] OR pakistan[MeSH] OR panama[MeSH] OR papua new guinea[MeSH] OR paraguay[MeSH] OR peru[MeSH] OR philippines[MeSH] OR poland[MeSH] OR portugal[MeSH] OR puerto rico[MeSH] OR romania[MeSH] OR russia[MeSH] OR rwanda[MeSH] OR samoa[MeSH] OR sao tome and principe[MeSH] OR saudi arabia[MeSH] OR senegal[MeSH] OR serbia[MeSH] OR seychelles[MeSH] OR sierra leone[MeSH] OR slovakia[MeSH] OR slovenia[MeSH] OR melanesia[MeSH] OR somalia[MeSH] OR south africa[MeSH] OR south sudan[MeSH] OR sri lanka[MeSH] OR saint kitts and nevis[MeSH] OR saint lucia[MeSH] OR saint vincent and the grenadines[MeSH] OR sudan[MeSH] OR suriname[MeSH] OR syria[MeSH] OR tajikistan[MeSH] OR tanzania[MeSH] OR thailand[MeSH] OR timor leste[MeSH] OR togo[MeSH] OR tonga[MeSH] OR trinidad and tobago[MeSH] OR tunisia[MeSH] OR turkey[MeSH] OR turkmenistan[MeSH] OR uganda[MeSH] OR ukraine[MeSH] OR uruguay[MeSH] OR uzbekistan[MeSH] OR vanuatu[MeSH] OR venezuela[MeSH] OR vietnam[MeSH] OR middle east[MeSH] OR yemen[MeSH] OR yugoslavia[MeSH] OR zambia[MeSH] OR zimbabwe[MeSH] OR africa south of the sahara[MeSH] OR africa, central[MeSH] OR africa, northern[MeSH] OR africa, southern[MeSH] OR africa, eastern[MeSH] OR africa, western[MeSH] OR west indies[MeSH] OR indian ocean islands[MeSH] OR caribbean region[MeSH] OR central america[MeSH] OR latin america[MeSH] OR south america[MeSH] OR asia, central[MeSH] OR asia, northern[MeSH] OR asia, southeastern[MeSH] OR asia, western[MeSH] OR europe, eastern[MeSH] OR developing countries[MeSH])

Annex 3: Quality Assessment for Studies Included in Framework Development

There is growing consensus that quality assessment is necessary for observational studies included in systematic review, yet there is disagreement about the method used to assess quality (Mallen, Peat, and Croft 2006; Sanderson, Tatt, and Higgins 2007; Lang and Kleijnen 2010). One major divergence in the current tools available for assessing quality in observational studies is the difference in tools designed to assess the quality of *the actual study* and tools designed to assess the quality of *reporting* (Ma et al. 2020). A common example of a tool to assess the quality of reporting in observational studies is the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) tool, however these guidelines are not meant to function as a quality assessment for studies (von Elm et al. 2007). Evaluating the quality of the underlying study is preferable in the context of translating findings into the development of a new framework. Two commonly used tools to assess quality of observational studies include the Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomized studies in meta-analysis and the Appraisal tool for Cross-Sectional Studies (AXIS tool). Previous researchers could not find materials describing the development process for the NOS tool published in peer-reviewed journals (Stang 2010). On the other hand, the AXIS tool was developed with a systematic Delphi process, which was documented and published in a peer-reviewed journal (Downes et al. 2016). Therefore, this quality assessment relies on the AXIS tool to determine the quality of the studies which inform the development of a framework for measuring the cascade of hypertension management services. Additionally, the quality assessment compiles the scores on the AXIS tool and provides justification for why each study was included in the framework development.

AXIS Quality Assessment for Introduction and Methods Sections

	Introduction	Methods									
Study	Were aims and objectives clear?	Was study design appropriate for stated aims?	Was sample size justified?	Was target population clearly defined?	Was sample frame taken from an appropriate population base?	Was selection process likely to select subjects that were representative of the target population?	Were measures taken to address and categorize non-responders?	Were the risk factor and outcome variables measured appropriate to the aims of the study?	Were the risk factor and outcome variables measured correctly using instruments/measurements that had been trialed, piloted, or previously published?	Is it clear what was used to determine statistical significance and/or precision estimates?	Were methods (including statistical methods) sufficiently described to enable them to be repeated?
Agudelo (2019)	Y	Y	Y	Y	Y	N (health areas purposively selected, but subunits and patients randomly selected)	Y	Y	Y	Y	Y
Arrendondo (2018)	Y	Y	N (used existing state-level data)	N	N	N	N	Y	Y	N/A	N/A
Bhandari (2015)	Y	Y	Y	Y	Y	Y	Y	Y	N (outcome of blood pressure was adequately measured but adherence was measured through self-report)	Y	Y
Charoendee (2018)	Y	Y	N	Y	Y	Y	N/A (analysis was aggregated to the province level)	Y	Y	N	N
Chukwuma (2019)	Y	Y	N	Y	N	N	N	Y	Y	N/A	Y
Gabert (2017)	Y	Y	N	Y	Y	Y	N	Y	Y (provided tools for household survey, process for bp measurement was not well described)	N/A	Y
Galson (2017)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Hashiguichi (2019)	Y	Y	N	N	N/A	N	Y	Y	N (bp measurement was not well described)	N/A	N
Heller (2020)	Y	Y	N (it was justified in other referenced studies)	Y	Y	Y	Y (non-response was treated as a result)	Y	Y	Y	Y
Ikeda (2020)	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y

	Introduction	Methods									
Study	Were aims and objectives clear?	Was study design appropriate for stated aims?	Was sample size justified?	Was target population clearly defined?	Was sample frame taken from an appropriate population base?	Was selection process likely to select subjects that were representative of the target population?	Were measures taken to address and categorize non-responders?	Were the risk factor and outcome variables measured appropriate to the aims of the study?	Were the risk factor and outcome variables measured correctly using instruments/measurements that had been trialed, piloted, or previously published?	Is it clear what was used to determine statistical significance and/or precision estimates?	Were methods (including statistical methods) sufficiently described to enable them to be repeated?
Jayanna (2019)	Y	Y	Y	Y	N (don't know if providers list was a census)	Y	N	Y	Y	Y	Y
Khanam (2014)	Y	Y	N	Y	Y	Y	N	Y	N (no description of items used to measure adherence)	Y	Y
Leslie (2019)	Y	Y	Y (with theory rather than calculation)	Y	Y	Y	N	Y	Y	Y	Y
Liu (2008)	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y
Lozano (2006)	Y	Y	N	Y	N/A (all of the sampling information was on a supplemental webpage which no longer is functional)	N/A	N/A	N/A	N/A	Y	Y
Mackino (2018)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Thorogood (2007)	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Wollum (2018)	Y	Y	N	Y	N	N (population data was from DHS but the facility survey was convenience sample)	Y (in the facility survey)	Y	Y (IHME tool was used)	Y	N
Zack (2016)	Y	Y	Y (used entire census)	Y	Y	Y	Y	Y	Y	Y	Y
Zhao (2020)	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y

AXIS Quality Assessment for Results, Discussion, and Other Sections

	Results					Discussion		Other		Judgement	
Study	Were the basic data adequately described?	Is there an acceptable non-response rate (<20%)*	Was information about non-responders described?	Were results internally consistent?	Were results presented for all analyses described in methods?	Were the authors' discussions and conclusions justified by the results?	Were the limitations of the study discussed?	Are authors' interpretations of results independent of funding declarations or conflicts of interest?*	Was ethical approval or consent of participants attained?	Overall AXIS score (out of 20)	Why was this study included in the final framework?
Agudelo (2019)	Y	Y	Y	Y	Y	Y	Y	Y	Y	19	High quality study which provided information about process quality (type of treatment and adherence)
Arrendondo (2018)	N	N/A	N	Y	Y	Y	Y	Y	N/A	9	Not an observational study, but a discussion piece which defines effective coverage for hypertension management services
Bhandari (2015)	Y	Y	Y	Y	Y	Y	Y	Y	Y	19	High quality study which provided information about process quality (type of treatment and adherence)
Charoendee (2018)	Y	N/A	N/A	Y	Y	Y	Y	Y	Y	14	Defines effective coverage of hypertension screening services, which supports the need for an expanded care cascade
Chukwuma (2019)	Y	N/A	N/A	Y	Y	Y	Y	Y	Y	13	Uses a hypertension care cascade with supply- and demand-side factors (including structural quality) to explain service coverage
Gabert (2017)	Y	N	N	N (text did not match figures)	Y	Y	Y	Y	Y	14	Uses a hypertension care cascade with supply- and demand-side factors (including structural quality) to explain service coverage
Galson (2017)	Y	Y (household was 15%, individual was 20.6%)	Y	Y	Y	Y	Y	Y	Y	20	High quality study which provided information about process quality (type of treatment)
Hashiguichi (2019)	Y	N/A	N	Y	Y	Y	Y	Y	Y	11	Defines effective coverage for hypertension management services
Heller (2020)	Y	Y	Y	Y	Y	Y	Y	Y	Y	19	High quality study which documents process quality (referral) throughout the hypertension care cascade (from screening to treatment to control)
Ikeda (2020)	Y	N (response rate of about 50%)	N	N	Y	Y	Y	Y	N/A	16	High quality study which defines effective coverage for hypertension management services
Jayanna (2019)	Y	Y	N	Y	Y	Y	Y	Y	Y	17	High quality study which documents components of service quality
Khanam (2014)	Y	N/A	N	Y	Y	Y	Y	Y	Y	15	Describes process quality (adherence to treatment)
Leslie (2019)	Y	N/A	N	Y	Y	Y	Y	Y	Y	17	High quality study which defines effective coverage for hypertension management services and multiple measures of outcome

	Results					Discussion		Other		Judgement	
Study	Were the basic data adequately described?	Is there an acceptable non-response rate (<20%)*	Was information about non-responders described?	Were results internally consistent?	Were results presented for all analyses described in methods?	Were the authors' discussions and conclusions justified by the results?	Were the limitations of the study discussed?	Are authors' interpretations of results independent of funding declarations or conflicts of interest?*	Was ethical approval or consent of participants attained?	Overall AXIS score (out of 20)	Why was this study included in the final framework?
											quality (non-hospitalization and bp control)
Liu (2008)	Y	N/A	N	Y	Y	Y	Y	Y	Y	16	High quality study which defines effective coverage for hypertension management services
Lozano (2006)	Y	N/A	N	Y	Y	Y	Y	Y	Y	12	Process documentation for measuring effective coverage which clearly defines a measure for hypertension management services
Mackino (2018)	Y	Y	N	Y	Y	Y	N	Y	Y	18	High quality study which describes process quality (obtaining quality care) on a hypertension care cascade
Thorogood (2007)	Y	N (non-response of 23%)	N	Y	Y	Y	N	Y	Y	16	High quality study which describes barriers related to structural quality on hypertension care cascade
Wollum (2018)	Y	N/A	Y	Y	Y	Y	Y	Y	Y	15	Describes process quality and supply-side barriers to hypertension care
Zack (2016)	Y	N (non-response rate of 53%)	Y	Y	Y	Y	Y	Y	Y	19	High quality study which describes process quality (patient adherence)
Zhao (2020)	Y	Y	N	Y	Y	Y	Y	Y	Y	19	High quality study which defines effective coverage for hypertension management services

**Indicates questions that were revised from original AXIS tool so that affirmative answers were positively interpreted*

Annex 4: World Bank Reports with Service Quality and Measures of Hypertension Management Coverage

Author, year	Study Type/Data source	Study population	Cascade of Care	Quality Measure Reported	Notes
(World Bank 2018)	Longitudinal Cohort study , patient files from clinics	South Africa: 4 Districts (Bojanala, Ekurhuleni, Mopani, and King Cetshwayo) Adults 18 and older	Diagnosed Initiated treatment One or more visits within first 3 months Visit or BP measure at 6 months Disease control achieved	Visit compliance in the first 3 months Initiated on hypertension treatment Regimen at initiation Retention in care	Also had a hypertension screening cascade
(World Bank 2019)	Cross-sectional DHS and SPA data	Bangladesh (national) Adults 18 and older	Hypertensive Diagnosed Treated BP controlled	Percent of health facilities providing CVD services Percent of facilities with CVD medication available	Reported supply- and demand-side barriers in the continuum of care to screening/diagnosis, treatment initiation, treatment monitoring, and treatment adherence/disease control
(World Bank 2020)	Mixed-methods (Cross-sectional) Household survey, patient file data extraction, focus group discussions with patients and care providers	Samoa: two islands (Upolu and Savai'i) Adults 20 and older	Hypertensive BP screened Diagnosed Treatment initiated BP monitored according to standards BP controlled	Availability of medicines and equipment Treatment advice from doctors Adherence	Reported barriers and facilitators at each stage in the hypertension cascade

Annex 5: Prescription Rating Protocol

Clinical Vignettes

1. Prescriptions will be classified into three different categories:
    1.1. Appropriate: Correct type of medication was prescribed as indicated, with appropriate dosage, frequency, and duration.
    1.2. Inappropriate, but not harmful: Prescription was missing one or more key medications as indicated by the primary diagnosis.
    1.3. Inappropriate, and harmful: If one or more medication in the prescription may directly cause harm in patients, breastfed infants, or fetus based on the type of medication and/or dosage.
2. Prescriptions will be rated as a whole, rather than individual drugs. (i.e. if one medication is classified harmful, then complete prescription will be marked as inappropriate and harmful)
3. Incomplete prescription will be marked as inappropriate. (e.g. ORS not prescribed in diarrhea)
4. Reviewer, to the best of their ability, will search for the generic analog of any brand names prescribed and will rate each medication based on their generic component/ active ingredients.
5. Homeopathic medications not recognized by the reviewer will be highlighted and will be excluded from the rating.
6. If the medication is not prescribed for the main diagnosis (e.g. hypertension) and the secondary issue is taken care of (e.g. headache), therefore the prescription will be marked as inappropriate

7. Drug appropriateness with diagnosis will be rated based on the primary diagnosis of the clinical vignettes and patient observation, differential diagnoses will be disregarded. For each relevant cases, the below clinical guidelines may be used:

7.1. Diarrhea in children: WHO Integrated Management of Childhood Illness (IMCI),

7.2. Acute respiratory infection (ARI) with fever in children: WHO Integrated Management of Childhood Illness (IMCI)

7.3. Angina pectoris in adult: American Heart Association's Advance Cardiac Life Support (pre-hospital section).

7.4. Adult hypertension: India's Standard Treatment Guideline of Hypertension by National Health Mission, Ministry of Health & Family Welfare Government of India

8. Drug-Drug interaction and drug-disease will be assessed, and if harmful interaction occurs, the prescription will be rated as inappropriate and harmful.

10. Unnecessary duplications of drug with the same indication will be rated as inappropriate.

11. For patient observations, prescription appropriateness will be rated pertaining to each main diagnosis given by the provider. For cases where no diagnosis was given, prescription will be rated based only on the drug's dosage, frequency and duration to determine if it is harmful or not.

Annex 6: Analysis of Associated Factors of Hypertension Screening and Diagnosis

Logistic regression analyses were conducted to determine predictors of individual receipt of services, specifically the probability of ever being screened, the probability of being diagnosed as hypertensive, and the probability of hypertensive individuals bypassing all local providers to seek care. For these analyses, individual variables were considered based on a conceptual framework for hypertension management. Considered variables included individual age, sex, occupation, education, caste, wealth quintile, average monthly income, religion, comorbidity, and current tobacco use, household variables such as other member of household with diagnosed hypertension and distance to PHC, and community level variables such as village-level wealth and service availability. For each regression analysis, collinearity of explanatory variables was assessed, a likelihood ratio test was conducted for each variable, effect modification was considered and tested, and the final model was compared with stepwise model selections. Hosmer-Lemeshow tests for goodness of fit were conducted and regression diagnostics were conducted to assess final model fit.

Predictors of Hypertension Screening

The probability of ever having blood pressure measured was assessed for all individuals over the age of 30 included in our study (n= 14,382). The final model suggests that the presence of comorbidities, age, sex, wealth quintile, household hypertension, education, religion, and caste all influence an individual's probability of ever having blood pressure measured. Women were 4.6 times more likely to report ever having their blood pressure measured than men (95% CI of 3.4 to 6.2 times more likely) although this relationship was modified by age.

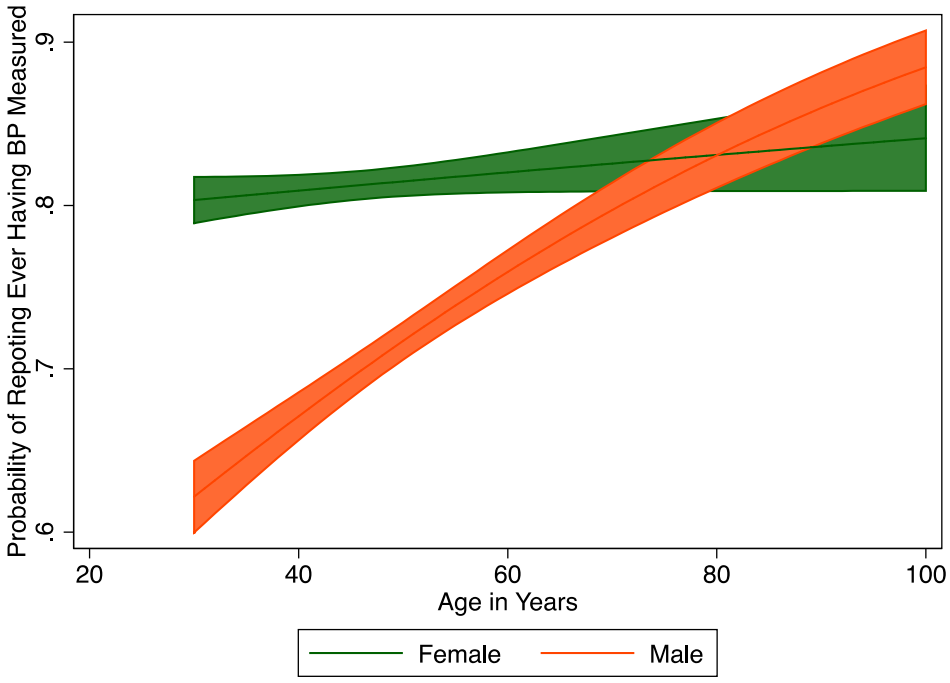
Logistic regression results for probability of having blood pressure measured

Variable	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Comorbidity	7.978	1.5	11.05	0	5.519	11.532	***
Sex							
Female (ref)	1	.	.	.	.	.	
Male	.217	.033	-10.06	0	.161	.292	***
Age and Sex							
Age (years)	1.004	.002	1.63	.104	.999	1.008	
Female * Age (ref)	1	.	.	.	.	.	
Male * Age	1.019	.003	6.23	0	1.013	1.026	***
Wealth							
Poorest wealth quintile (ref)	1	.	.	.	.	.	
Poorer wealth quintile	1.214	.072	3.25	.001	1.08	1.365	***
Middle wealth quintile	1.241	.073	3.69	0	1.107	1.393	***
Richer wealth quintile	1.317	.089	4.06	0	1.153	1.504	***
Richest wealth quintile	1.83	.131	8.47	0	1.591	2.105	***
Household hypertension	1.663	.119	7.09	0	1.445	1.914	***
Education							
No education (ref)	1	.	.	.	.	.	
Some schooling	1.196	.059	3.62	0	1.085	1.317	***
Higher secondary schooling or above	1.548	.136	4.98	0	1.304	1.838	***
Religion							
Hindu (ref)	1	.	.	.	.	.	
Muslim	1.421	.113	4.42	0	1.216	1.661	***
Caste							
Scheduled Caste (ref)	1	.	.	.	.	.	
Scheduled Tribe	1.107	.199	0.57	.571	.779	1.574	
Other Backwards Caste	1.065	.051	1.31	.189	.969	1.171	
General Caste	1.379	.118	3.77	0	1.167	1.63	***
Constant	1.487	.216	2.73	.006	1.118	1.977	***

Mean dependent var	0.768	SD dependent var	0.422
Pseudo r-squared	0.058	Number of obs	14330.000
Chi-square	895.776	Prob > chi2	0.000
Akaike crit. (AIC)	14671.443	Bayesian crit. (BIC)	14792.565

*** p<.01, ** p<.05, * p<.1*

Figure: Probability of reporting ever having blood pressure measured in rural Bihar by age and sex



Predictors of Hypertension Diagnosis

Similar to the model for probability of hypertension screening, wealth, age, comorbidity, caste, education, and sex were significantly associated with the probability of hypertension diagnosis. Females were significantly more likely to be diagnosed than males at all ages, however there was a changing relationship in terms of probability of diagnosis starting at age 60. After age 60, the richer two wealth quintiles were significantly more likely to be diagnosed than the poorest three wealth quintiles, suggesting that the rich elderly have better access to care than the poor.

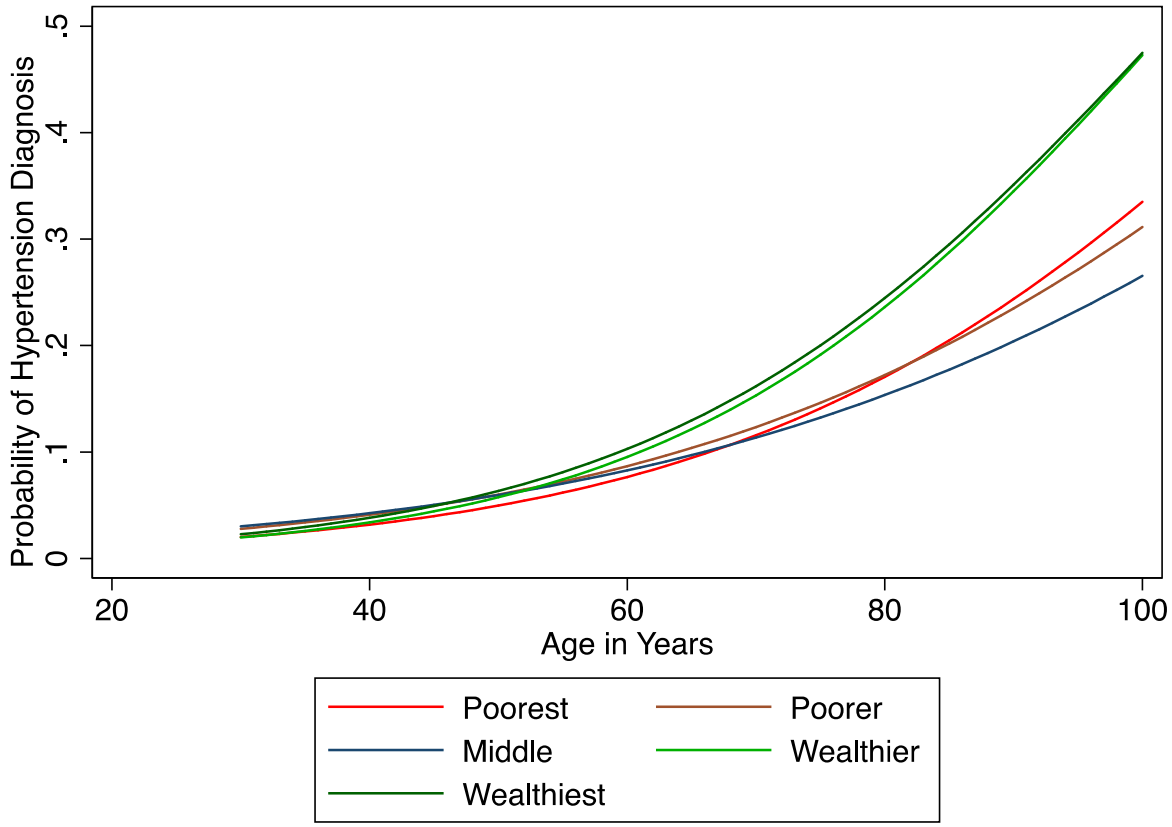
Regression results for individual probability of hypertension diagnosis

Variable	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Wealth							
Poorest wealth quintile (ref)	1	.	.	.	.	.	
Poorer wealth quintile	1.692	.775	1.15	.251	.69	4.15	
Middle wealth quintile	2.12	.938	1.70	.089	.891	5.045	*
Richer wealth quintile	.745	.369	-0.59	.553	.283	1.966	
Richest wealth quintile	.924	.412	-0.18	.859	.386	2.213	
Age and Wealth							
Age (Years)	1.049	.006	8.43	0	1.037	1.06	***
Poorest quintile * Age (ref)	1	.	.	.	.	.	
Poorer quintile * Age	.994	.008	-0.82	.412	.978	1.009	
Middle quintile * Age	.989	.007	-1.47	.142	.974	1.004	
Richer quintile * Age	1.009	.008	1.08	.279	.993	1.026	
Richest quintile * Age	1.007	.007	0.94	.349	.992	1.022	
Comorbidity	3.808	.339	15.01	0	3.198	4.535	***
Caste							
Scheduled Caste (ref)	1	.	.	.	.	.	
Scheduled Tribe	1.551	.535	1.27	.203	.789	3.049	
Other Backwards Caste	1.442	.144	3.67	0	1.186	1.753	***
General Caste	2.099	.264	5.90	0	1.641	2.685	***
Education							
No education (ref)	1	.	.	.	.	.	
Some schooling	1.404	.121	3.92	0	1.185	1.663	***
Higher secondary schooling or above	1.793	.254	4.13	0	1.359	2.366	***
Sex							
Female (ref)	1	.	.	.	.	.	
Male	.565	.046	-6.97	0	.481	.663	***
Constant	.003	.001	-16.84	0	.002	.006	***

Mean dependent var	0.066	SD dependent var	0.248
Pseudo r-squared	0.114	Number of obs	14377.000
Chi-square	796.134	Prob > chi2	0.000
Akaike crit. (AIC)	6230.517	Bayesian crit. (BIC)	6359.264

**** p<.01, ** p<.05, * p<.1*

Figure: Probability of being diagnosed as hypertensive in rural Bihar by age and wealth quintile



Predictors of Bypassing among Hypertensives

In this analysis, bypassing was defined as those who travel more than 5 km beyond their local PHC to receive hypertension management services. Caste, wealth quintile, education, and comorbidities were all significantly associated with bypassing local options for hypertension management. In general, the most advantaged members of society (wealthiest and from general caste) receive care from different sources than the rest of society. Also, individuals with comorbidities tend to bypass local options, suggesting an inability of local providers to provide complex care.

Regression results for individual probability of bypassing local providers for hypertension management services

Variable	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Caste							
Scheduled Caste (ref)	1	.	.	.	.	.	
Scheduled Tribe	2.621	1.836	1.38	.169	.664	10.344	
Other Backwards Caste	1.727	.412	2.29	.022	1.082	2.755	**
General Caste	2.262	.629	2.94	.003	1.312	3.901	***
Wealth							
Poorest wealth quintile (ref)	1	.	.	.	.	.	
Poorer wealth quintile	1.628	.412	1.93	.054	.992	2.674	*
Middle wealth quintile	1.224	.312	0.79	.428	.743	2.017	
Richer wealth quintile	1.319	.344	1.06	.289	.791	2.198	
Richest wealth quintile	1.799	.441	2.40	.017	1.113	2.91	**
Age	1.004	.006	0.71	.479	.993	1.016	
Sex							
Female (ref)	1	.	.	.	.	.	
Male	1.012	.195	0.06	.949	.695	1.475	
Education							
No education (ref)	1	.	.	.	.	.	
Some schooling	1.403	.253	1.88	.06	.985	1.998	*
Higher secondary schooling or above	1.991	.601	2.28	.023	1.101	3.599	**
Comorbidity	2.476	.412	5.45	0	1.787	3.431	***
Years since hypertension diagnosis	1.006	.014	0.41	.678	.979	1.034	
Constant	.114	.049	-5.09	0	.049	.263	***

Mean dependent var	0.363	SD dependent var	0.481
Pseudo r-squared	0.070	Number of obs	906.000
Chi-square	83.645	Prob > chi2	0.000
Akaike crit. (AIC)	1133.578	Bayesian crit. (BIC)	1205.713

*** $p<.01$, ** $p<.05$, * $p<.1$

Annex 7: Age-Standardized Calculation of Hypertension Prevalence in Bihar, India

	Men		Women		Total	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Hypertension Prevalence*		18.10%		15.80%		17.03%
Percent of Adults over 30 Screened #		73.79%		80.63%		77.47%
Percent of Adults 30-49 Screened #		67.95%		80.16%		75.03%
Percent of Adults over 50 Screened #		79.41%		81.27%		80.32%
Percent of Adults over 30 Diagnosed #		6.01%		7.12%		6.31%
Percent of Adults 30-49 Diagnosed #		2.44%		3.26%		2.92%
Percent of Adults over 50 Diagnosed #		9.08%		11.52%		10.28%
Bihar Rural Population +	48,073,850		44,267,586		92,341,436	
Bihar Rural Adult (15 and older) Population +	29,866,777		25,996,835		55,863,613	
Bihar Rural Adult (15-49) Population +	23,482,572	78.62%	20,176,831	77.61%	43,659,404	
Bihar Rural Adult (50 and older) Population +	6,384,205	21.38%	5,820,004	22.39%	12,204,209	
Individuals with Hypertension	5,405,886.64	18.10%	4,107,499.93	15.80%	9,513,386.75	17.03%
Age-standardized population ever screened	21,026,104.86	70.40%	20,903,664.98	80.41%	42,560,071.50	76.19%
Age-standardized Diagnosed Individuals	1,308,435	4.38%	1,517,961	5.84%	2,885,810	5.17%
Age-standardized Undiagnosed Individuals	4,097,451.46		2,589,538.65	0.06	6,627,576.55	

Legend:

Symbol	Source	Link	Location	Notes
*	NFHS-5 Bihar Fact Sheet	http://rchiips.org/nfhs/NFHS-5_FCTS/FactSheet_BR.pdf	Page 5	Age-standardization for hypertension prevalence not available
+	Census 2011	https://censusindia.gov.in/2011census/C-series/C-13.html	Table C-13	
#	Bihar Assessment of Primary Health Care System	NA	Data available upon reasonable request	

Annex 8: Hypertension Vignette

Interviewer explains to the provider: Thank you for your time and willingness to participate. We'd like to do an exercise. I will now come to you pretending to be a patient in four different scenarios. Please interact as if I were a real patient, and how you would approach a similar scenario. We would like you to ask all questions and demonstrate examination that you would do in a real situation (whether on this doll for a child, or on me for an adult patient), and then let us know what you would do for the patient. Do you have any questions, or aspect we can clarify?

Case 1

Interviewer: I am a 55-year-old female patient coming to you with headache, and a prior high blood pressure

Section I: History **खंड 1 : इतिहास** ***Interviewer: "What are ALL the important questions you will ask me now?"*** ***साक्षात्कर्ता : ''आप अब मुझसे क्या-क्या महत्वपूर्ण प्रश्न पूछेंगे/गी?''***			
No.	**Provider Response** **प्रोवाइडर का रिस्पांस** **Asked 1; Not Asked 2** **पूछा - 1, नहीं पूछा - 2**	**Type of Questions** **प्रश्नों का प्रकार**	**Patient's Response** **मरीज के उत्तर**
101		Where is your headache, and what is it like?	Temples, dull ache, constant
		Any other questions on the headache, respond No	No
102		Do you smoke?	Yes हां
103		Do you have any other medical conditions? E.g. Diabetes?	No
104		Have you had any other symptoms? (Chest pains, dizziness, shortness of breath, swelling in lower limbs, blurry vision)	No
105		Have you been advised to or have you made any change in diet (increased vegetables, reduced salt in cooking_	No
106		Have you been advised to or have you stopped smoking?	No
107		Have you been advised to or have you stopped alcohol intake?	No

108		Have you been advised to or have you increased your exercise?	No
109		*Any additional question about other symptoms* अन्य किसी लक्षण से जुड़े कोई प्रश्न	*No* नहीं
110		*Any additional question about pattern/ duration/ type of illness etc* पैटर्न/अंतराल/बीमारी के प्रकार से जुड़े कोई अन्य प्रश्न?	*I don't remember* मुझे याद नहीं
111	**No. of questions asked by the provider *(record using tally marks)*:** ***प्रदाता द्वारा पूछे गए प्रश्न(संख्या को जोड़ का लिखे)***		
Section II: Examination **खंड II: प्रशिक्षण** ***Interviewer: "What physical examinations will you conduct?"*** ***साक्षात्कारकर्ता: "आप कौन से शारीरिक प्रशिक्षण करेंगे?"***			
No.	**Provider Response** **प्रोवाइडर का रिस्पांस** **Done 1; Not Done O** **किया – 1, नहीं किया - 0**	**Type of Examinations** **परिक्षण का प्रकार**	**Patient's Response** **मरीज के उत्तर**
112		BP बिपि	150/90
113		Second measure of BP	150/90
114		Pulse	Normal
115		Used stethoscope to examine chest and heart स्टेथोस्कोप का इस्तेमाल कर के छाती और ह्रदय की जांच करें	Normal सामान्य
116		*Any additional examination mentioned (or height or weight)* अन्य कोई जांच का उल्लेख किया गया (या लम्बाई या वजन)	*Normal* सामान्य
Section III: Final Diagnosis **खंड 3: सुनिश्चित रोग** ***Interviewer: "What is your diagnosis based on the above information?"*** ***साक्षात्कारकर्ता: " ऊपर दी हुई जानकारी के आधार पर आप किस रोग की पहचान करेंगे?"***			
117	1. Hypertension/High BP		

	88. Other. specify_	
Section IV: Treatment **खंड IV: इलाज**		
118	***Interviewer: "How will you manage the case?"*** *साक्षात्कारकर्ता: " आप इस अवस्था का प्रबंधन कैसे करेंगे?"* ***(Read out the options below and circle the relevant one)*** *(सारे विकल्प पढ़े और 1 सबसे उचित जवाब में गोला लगाए)* No referral, treat the person at the facility itself कोई रेफरल नहीं, मरीज़ का इलाज़ स्वास्थ्य संस्था में ही हो जाएगा ……..1 Referral, with some treatment at this facility रेफर करेंगे, स्वास्थ्य संस्था में प्राथमिक इलाज़ के बाद …….....2 Referral, without any treatment रेफर करेंगे, बिना किसी प्राथमिक इलाज़ के …….....3	*(If 1 or 2 proceed to 117; if 3 proceed to next case)* अगर 1 या 2 तो 117 पर जाए; अगर 3 तो अगले केस पर जाए
119	***Interviewer: Do you think there is a need for a follow-up check?"*** ***साक्षात्कर्ता : ''क्या आप रोगी को फॉलो-अप जांच के लिए दुबारा बुलाएंगे?***	Yes/No हां/ नहीं
120	***Interviewer: "What medicines will you prescribe?"*** *साक्षात्कर्ता : ''आप क्या इलाज प्रेस्क्राइब करेंगे/गी?''* ***Ask the provider and note the following details.***	

	Type **प्रकार** *(Enter Tab, Syrup, Injection)* *(लिखें– गोलियां, सीरप या सुई)*	**Name** **नाम**	**Dose** **खुराक**	**Frequency** **रोज कितनी बार**	**Duration (days)** **कितने दिनों तक**
A					
B					
C					
D					

121	***Interviewer: "What advice would you give to the patient?"*** *SELECT ALL THAT ARE MENTIONED BY THE PRACTITIONER* ***साक्षात्कर्ता : ''आप रोगी के लिए किन अन्य चीजों की अनुशंसा करेंगे/गी?''*** 1. No advice 2. Explained that hypertension is a lifelong condition, needing daily medication and regular follow up and monitoring 3. Alert to danger signs (persistent chest pain, dizziness/fainting, worsening shortness of breath) 4. Alert to complications (heart attack/stroke, aneurysm, heart failure, etc.) 5. Adequate diet, with reduced salt intake 6. Regular exercise/physical activity 7. Smoking cessation 8. Monitor high blood pressure 88. Others, specify
122	**Interviewer: Are there any danger signs that the patient should watch out for?** *SELECT ALL THAT ARE MENTIONED BY THE PRACTITIONER* 1. Persistent chest pain lasting more than a few minutes 2. Dizziness/Fainting/severe light-headedness/lose consciousness 3. Worsening shortness of breath, severe difficulty of breathing, swelling in feet 4. Blurry vision 88. Others, specify

Annex 9: Average and Rank Difference in Provider Quality Scores by Division

Division	**Tabulation of all elements**	**Rank**	**Simple Quality Score**	**Rank**	**Simple plus Structural Quality**	**Rank**	**Simple plus Structural and Danger**	**Rank**
Bhagalpur	37.6	2	51.9	3	51.4	4	52.7	1
Darbhanga	35.9	6	51.7	4	52.3	3	46.6	6
Kosi	37.3	3	52.7	2	53.3	2	50.3	3
Magadh	35.7	7	50.1	5	50.1	5	46.3	7
Munger	33.3	8	44.7	9	44.1	9	41.3	9
Patna	37.1	4	48.3	7	48.4	8	47.0	4
Purnia	39.7	1	56.9	1	54.3	1	50.9	2
Saran	32.5	9	49.7	6	48.5	7	45.9	8
Tirhut	36.6	5	47.5	8	49.6	6	47.0	5
Overall Average	36.1		49.6		49.8		46.8	
Range	7.1		12.3		10.2		11.4	

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Wagstaff, Adam, Gabriela Flores, Justine Hsu, Marc-François Smitz, Kateryna Chepynoga, Leander R Buisman, Kim van Wilgenburg, and Patrick Eozenou. 2018. "Progress on Catastrophic Health Spending in 133 Countries: A Retrospective Observational Study." *The Lancet Global Health* 6 (2): e169–79. https://doi.org/10.1016/S2214-109X(17)30429-1.

Whelton, Paul K., Robert M. Carey, Wilbert S. Aronow, Donald E. Casey, Karen J. Collins, Cheryl Dennison Himmelfarb, Sondra M. DePalma, et al. 2018. "2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Pr." *Journal of the American College of Cardiology* 71 (19): e127–248. https://doi.org/10.1016/j.jacc.2017.11.006.

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Zhao, Y, A S Mahal, S Tang, T N Haregu, and B Oldenburg. 2020. “Effective Coverage for Hypertension Treatment among Middle-Aged Adults and the Older Population in China, 2011 to 2013: A Nationwide Longitudinal Study.” *Journal of Global Health* 10 (1).

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Zuccala, Elizabeth, and Richard Horton. 2020. “Reframing the NCD Agenda: A Matter of Justice and Equity.” *The Lancet* 396 (10256): 939–40.

Curriculum Vitae

Michael Alexander Peters

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PROFILE

Doctoral student in international public health with a focus on implementation science and health systems research. Dissertation research on improving access, quality, and effective coverage of hypertension management services in Bihar, India. Experience in global health research and practice with skills in robust data analysis, excellent written and oral communications, and a proven history of collaboration with local and international partners. Strong work ethic and team skills with a range of quantitative, spatial, and qualitative analytic and software competencies.

EDUCATION

Doctor of Philosophy (Candidate) Baltimore, MD
Johns Hopkins Bloomberg School of Public Health (JHSPH) *Expected July 2021*

- International Health, Health Systems: GPA: 4.0
- Thesis: *Measuring Health Systems Performance in the Non-Communicable Disease Era: Improving effective coverage of hypertension management services in Bihar, India*
- Delta Omega Public Health Honorary Society Member, Alpha Chapter
- Highlighted Coursework: Organizational Leadership, Financing Universal Health Coverage (UHC), Planning and Implementing Large Scale Evaluations, Multilevel Statistical Modeling, Qualitative Research and Data Analysis, Causal Inference

Master of Science in Public Health Baltimore, MD
Johns Hopkins Bloomberg School of Public Health (JHSPH) *2016-2018*

- International Health, Health Systems: GPA: 3.95
- Delta Omega Public Health Honorary Society Member, Alpha Chapter
- Highlighted Coursework: Implementation Research, Spatial Analysis, Longitudinal Data Analysis, Biostatistical Analysis, Budgeting and Financial Management, Quality Improvement Methods, Health Survey Research Methods, Epidemiologic Inference, Management Methods in LMICs, Health Systems in LMICs

Bachelor of Arts Middlebury, VT
Middlebury College *2011- 2015*

- Geography Major, Global Health Minor. Graduated *Magna Cum Laude*
- GPA: 3.72; College Scholar (highest academic honor) all eligible semesters
- Highlighted Coursework: Independent Study: Spatial and Temporal Analysis of the 2014 Ebola Outbreak, Geographic Information Systems (GIS) Fundamentals, Economic Statistics, Regression Analysis, Models in Epidemiology

EXPERIENCE

Consultant, Health Sector Group Manila, Philippines
Asian Development Bank *October 2018 - Present*

- Responding to the novel coronavirus (COVID-19) pandemic:

- Developing and processing a Technical Assistance grant worth $48.3 million to provide rapid response and capacity building in Asia and the Pacific
- Preparing and winning a $6 million grant from the Foreign, Commonwealth and Development Office to strengthen response in the Greater Mekong Subregion
- Supporting countries to obtain and deliver COVID-19 vaccines through the $9 billion APVAX initiative
- Chairing a weekly partners' meeting to coordinate COVID-19 response across the region (between ADB, WPRO, DFAT, IMF, and World Bank)
- Leading a series of Delphi studies to generate and disseminate evidence for best practice during early COVID-19 response
- Developing a comprehensive dashboard for tracking epidemiologic, economic, and political impacts of COVID-19 globally

- Coordinating and supporting a joint symposium of Ministers of Finance and Health with WHO to advance progress towards achieving UHC in Asia and the Pacific
- Developing and implementing ADB's Operational Plan for Health (2019-2030), including prioritizing strategic areas for expansion within the health sector
- Facilitating collaborations with external partners including US CDC, WHO WPRO and SEARO, The Global Fund, Resolve to Save Lives, Australia National University, and Johns Hopkins University

Research Assistant, Assessment of Primary Health Care in Bihar, India Patna, India
Bill and Melinda Gates Foundation, JHSPH *September 2019 - Present*

- Developing tools, conducting training, and supervising data collection to assess utilization of care and quality of services in Bihar
- Analyzing household and facility data to provide policy options for improving access and quality of health (especially NCD-related) services to underserved populations
- Coordinating with local partners (CARE India, GoB, and OPM) to ensure lasting relationships in the study area

Research Assistant, Lessons from Global Polio Eradication (STRIPE) Baltimore, USA
Bill and Melinda Gates Foundation, JHSPH *December 2017 – December 2019*

- Led a global survey on lessons learned from polio eradication, including designing the survey, coordinating across seven countries, and analyzing results
- Analyzed and synthesized knowledge and experiences from GPEI, academic and implementing partners to inform university and practice courses on delivery science
- Supported an academic consortium comprised of researchers from seven countries

Consultant, Healthy Societies Global Solutions Group Washington DC, USA
The World Bank *March 2018 - September 2018*

- Designed and conducted analysis on global NCD-related operations
- Prepared a framework for developing pandemic preparedness plans in African countries
- Supported research, analysis and synthesis on global pandemic preparedness and NCDs

Research Assistant, Real Accountability: Data Analysis for Results Zomba, Malawi
Institute for International Programs, JHSPH *March 2017 – March 2018*

- Refined and validated a national facility-based survey- "Implementation Strength Assessment of Family Planning" in Malawi
- Led in-country data management and analysis to guide survey implementation
- Developed GIS methods for linking DHS household data with health facility survey data

Head Teaching Assistant, Spatial Analysis in Public Health I, II, III, IV Baltimore, USA
Department of Epidemiology, JHSPH *September 2016 – Present*

- Designed graduate level lesson plans, taught classes, and guided discussions for in-person and online courses (17 courses to date)
- Tutored ArcGIS and QGIS program use, concepts of spatial analysis for public health data

Global Impact Corps Volunteer Tamale, Ghana
Unite for Sight *May - August 2014*

- Tested vision and observed sight restoring surgeries for hundreds of vulnerable patients
- Compiled and analyzed data to evaluate impact of Friends Eye Center

Monitoring and Evaluation Specialist, Health & HIV Programs Baltimore, USA
Catholic Relief Services, Health and HIV Unit *May - August 2013*

- Designed surveys to support monitoring and evaluation across country programs
- Prepared literature review and National Institutes of Health proposal on health literacy

ACADEMIC HISTORY

Selected Publications

- Rao, Krishna D, Japneet Kaur, **Michael A Peters**, Navneet Kumar, and Priya Nanda. 2021. "Pandemic Response in Pluralistic Health Systems: A Cross-Sectional Study of COVID-19 Knowledge and Practices among Informal and Formal Primary Care Providers in Bihar, India." *BMJ Open* 11 (4): e047334. https://doi.org/10.1136/bmjopen-2020-047334.
- **Peters, Michael A**., Diwakar Mohan, Patrick Naphini, Emily Carter, and Melissa A. Marx. 2020. "Linking Household Surveys and Facility Assessments: A Comparison of Geospatial Methods Using Nationally Representative Data from Malawi." *Population Health Metrics* 18 (1): 1–11. https://doi.org/10.1186/s12963-020-00242-z.
- **Peters, Michael A**., Wakgari Deressa, Malabika Sarker, Neeraj Sharma, Eme Owoaje, Riris Andono Ahmad, Tawab Saljuqi, Eric Mafuta, and Olakunle Alonge. 2020. "Sampling Method for Surveying Complex and Multi-Institutional Partnerships: Lessons from the Global Polio Eradication Initiative." *BMC Public Health* 20 (Suppl 2): 1–12. https://doi.org/10.1186/s12889-020-08592-x.
- Schleiff, Meike, Adetoun Olateju, Ellie Decker, Abigail H. Neel, Rasheedat Oke, **Michael A. Peters**, Aditi Rao, and Olakunle Alonge. 2020. "A Multi-Pronged Scoping Review Approach to Understanding the Evolving Implementation of the Smallpox and Polio Eradication Programs: What Can Other Global Health Initiatives Learn?" *BMC Public Health* 20 (Suppl 4): 1–13. https://doi.org/10.1186/s12889-020-09439-1.
- Owoaje, Eme, Ahmad Omid Rahimi, Anna Kalbarczyk, Oluwaseun Akinyemi, **Michael A. Peters**, and Olakunle O. Alonge. 2020. "Conflict, Community, and Collaboration: Shared Implementation Barriers and Strategies in Two Polio Endemic Countries." *BMC Public Health* 20 (Suppl 4): 1–12. https://doi.org/10.1186/s12889-020-09235-x.
- Alonge, Olakunle, Abigail H. Neel, Anna Kalbarczyk, **Michael A Peters**, Yodi Mahendradhata, Malabika Sarker, Eme Owoaje, et al. 2020. "Synthesis and Translation of Research and Innovations from Polio Eradication (STRIPE): Initial Findings from a Global Mixed Methods Study." *BMC Public Health* 20 (S2): 1176. https://doi.org/10.1186/s12889-020-09156-9.
- Rao, KD., Makimoto, S., **Peters, MA**., Leung, GM., Bloom, G., Katsuma, Y. (2019) Vulnerable Populations and Universal Health Coverage: Challenges and Policy Options. In Leave No One

Behind: Vulnerable Populations and the Sustainable Development Goals. Washington DC: Brookings Institute

- Peters, David H., **Michael A. Peters**, Kremlin Wickramasinghe, Patrick L. Osewe, and Patricia M. Davidson. 2019. "Asking the Right Question: Implementation Research to Accelerate National Non-Communicable Disease Responses." *BMJ (Online)* 365. https://doi.org/10.1136/bmj.l1868.

Manuscripts Under Review

- Osewe, P., Opio, A., **Peters, MA**. (2019) Is Africa Ready for the Next Pandemic? A Framework for Guiding African Countries in Developing their National Multisectoral Pandemic Preparedness and Response Plans. *World Bank Discussion Paper*

Manuscripts in Preparation

- Osewe, P., **Peters, MA**. (2020). Prioritizing public health investments for Coronavirus response and building resilient health systems: results from a Delphi exercise
- Osewe, P., **Peters, MA**. (2019). The Invisible Pandemic: Non-Communicable Diseases in Low- and Middle-Income Countries and the World Bank's efforts to reveal and alleviate the crisis

Acknowledgements:

- Marx, Melissa (2017). Role of Food Insecurity in Outbreak of Anthrax Infections among Humans and Hippopotamuses Living in a Game Reserve Area, Rural Zambia. *Emerging Infectious Diseases*, 23(9), 1471-1477.

Teaching History:

- American University of Armenia, Armenia (2021) – Public Health Program Planning and Evaluation. Co-lead instructor.
- Johns Hopkins University, USA (2016-2021) – Teaching Assistant
  - Spatial Analysis in Public Health I-IV (2016-2021): 17 courses overall, lead teaching assistant
  - School-Wide 2nd year DrPH Seminar (2020-2021): teaching assistant
  - Large-Scale Effectiveness Evaluations of Health Programs (2020): teaching assistant
  - Health Systems in Low- and Middle-Income Countries (2019): teaching assistant
  - Applications in Managing Health Organizations in Low- and Middle-Income countries (2019): teaching assistant
- Middlebury College, USA (2020, 2021) – The Role of Multilateral Development Banks in Global Public Health. Guest Lecture in "Communities in Global Health".

Scientific Presentations:

- Peters, Michael (2020). "Linking Household Surveys and Facility Assessments Using Geospatial Methods: A National Comparison in Malawi". Presented at the Sixth Global Symposium on Health Systems Research (*virtually*)
- Peters, Michael (2017). "Geographic Methods for Linking Facility and Household Health Surveys". Presented at GIS Day, JHSPH.

OTHER WORK HISTORY

Professional Ice Hockey Player (SPHL) Roanoke, VA
Roanoke Rail Yard Dawgs *November 2016*

Construction Worker – Stone Mason Sun Valley, ID
Big Rock Masonry *2015 - 2016*

Commercial Fisherman – Deckhand Petersburg, AK
Trident Seafoods *June – September 2015*

Goalie Coach & Youth Counselor Laurel, MD
Wolfe Hockey Development *2012 - 2020*

PROFESSIONAL DEVELOPMENT

- Software Skills: ArcGIS, STATA, R, Excel, ODK, Publisher, SharePoint, Keysurvey
- Language Skills: Conversational French, proficient writer

NCAA Ice Hockey Player Middlebury, VT
Middlebury College Panthers *2011 – 2015*

- Named to NESCAC All-Academic team 2012-2015; All-Sportsmanship team 2014-2015
- Awarded Most Improved Player 2012-2013, Buff Berman Character Award 2014-2015